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ABSTRACT

Included are three units related to coastal and oceanic awareness. The units are: (1) A Comparative Study of Clam and Squid; (2) Biting Flies of the Coastal Region; and (3) Diatoms: Nature's Aquatic Gems. All three units were designed for secondary school students. Each unit contains teacher background materials, student activity materials, evaluation materials, transparency masters, and selected references. (RH)

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227

ED141154

A COMPARATIVE STUDY OF CLAM AND SQUID

A Learning Experience for
Coastal and Oceanic
Awareness Studies

Produced by

MARINE ENVIRONMENT CURRICULUM STUDY
MARINE ADVISORY SERVICE
UNIVERSITY OF DELAWARE

and

POPULATION-ENVIRONMENT CURRICULUM STUDY
COLLEGE OF EDUCATION
UNIVERSITY OF DELAWARE

as part of a

PLAN FOR ENVIRONMENTAL EDUCATION

Fall 1974

SE 022 676

Please send evaluations

of learning experiences

to

Dr. Robert W. Stegner, Director

COAST Project

310 Willard Hall Education Building

University of Delaware

Newark, Delaware 19711

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TITLE: A COMPARATIVE STUDY OF CLAM AND SQUID

*CONCEPT: I.B.4.a.(3)

I. The earth is a finite natural system.

B. All living things have arisen from and are dependent upon the natural system of the earth.

4. The interaction of organisms with their environment leads to great diversity and wide distribution of organisms.

a. Natural selection leads to evolution.

(3) NATURAL SELECTION RESULTS FROM THE INTERACTION OF INDIVIDUAL VARIATIONS WITH ENVIRONMENT.

**MARINE CONCEPT: 3.21

3. Marine organisms interact in complex ecosystems.

3.2 Marine organisms are adapted to their environments in different ways.

3.21 MARINE ORGANISMS ARE ADAPTED DEVELOPMENTALLY, STRUCTURALLY, FUNCTIONALLY, AND BEHAVIORALLY TO THEIR ENVIRONMENTS.

SUBJECT: Life Science, Biology

GRADE LEVEL: 7-10

PERIODS: Various

AUTHOR: Workman

INSTRUCTIONAL OBJECTIVES:

At the conclusion of this unit, each student will be able to:

1. Draw and explain the locomotion process of the clam.
2. Identify the major features of the clam anatomy.
3. Draw and explain the means of locomotion for the squid.
4. Identify major features of the squid's anatomy.
5. Compare and contrast the anatomy and locomotion of the clam and the squid.

* From A Conceptual Scheme for Population-Environment Studies, 1973. Cost $2.50

** From Marine Environment Proposed Conceptual Scheme. 1973. No charge.

Both conceptual schemes are available from Robert W. Stegner, Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

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The Clam

I. Introduction to the study

A. Classroom activity: Set up a freshwater aquarium and obtain five small freshwater clams from a pond or stream. There should be at least five inches of sand in the bottom of the aquarium. Allow time for the class to observe the movement of the clams in the aquarium. Point out the slowness of their movement and the trails they leave behind.

B. Give the pre-test, p. 5

II. Study of clam anatomy--structure and function

A. Teacher preparation:

1. Obtain enough preserved clam specimens to allow one clam for two students. If you cannot get the clams from a biological supply house, you may use fresh clams which can be collected with a rake and a few hours of work. The fresh clams will be salt water forms from the local bay. The only disadvantage with using fresh clams is they will be difficult to open. Frequently the clam knife will split the foot or body mass before the clam opens. Preserved specimens come pre-opened with wooden pegs inserted between the shells.

2. Duplicate the clam dissection instructions. (See p. 12.)

3. Assemble the necessary dissection equipment.

B. Classroom procedure:

1. Hand out copies of the clam dissection instructions.

2. Show the overhead transparency of the clam's internal anatomy (p. 15).

3. Give a copy of the diagram of the clam's internal anatomy to each student. Identify each part on the transparency, making appropriate comments on the structure and function of each part. Have the students make notes necessary for retention of information. Walk around the classroom, asking each student to point to the part under discussion on his clam specimen. Make sure each student can locate the part under discussion before you move on. After all the parts have been identified, collect the clams and place them underwater in a bucket for a laboratory practical the next day. (Be sure to add some preservative to the water if the clams will be stored overnight.)

C. Lecture on clam locomotion:

1. Point out the location of the clam foot and show the overhead transparency of the locomotion of the clam (p. 17).

2. Make the following remarks:
The class of mollusks to which the clam belongs is Pelecypoda. The name of the group means hatchet foot. Most members of the group are marine but some species of clams are abundant in fresh water.

When undisturbed, the clam lies partly buried in the sand or mud with the hinge up and the shells slightly agape. In this position the animal protrudes its fleshy foot and burrows through the mud like a plowshare. First, the pointed foot is extended forward into the mud and anchored by a turning or swelling of the free end (due to an influx of blood into a cavity of the foot). When a moving clam extends its foot into the sand, the swollen tip acts as an anchor. The muscles of the foot contract, drawing the body of the clam forward. Such a slowly moving animal with a shell that is heavy and cumbersome to carry about could hardly run down its prey. Instead, like so many other relatively sedentary aquatic animals, the clam draws water through its body and strains out microscopic organisms and other nourishing organic particles contained in the water. For protection it relies on its heavy shell and retiring habits.

D. Give Post-test. (p. 7)
For the laboratory practical portion of the test (#6), of the 17 parts identified 10 may be tagged for identification (pins with numbered tags attached); or all may be tagged and students allowed to select 10. Alternately, the use of the dissected specimens can be omitted and a diagram without labels used to test students' knowledge of clam anatomy.
(see p.16)

The Squid

I. Introduction to the study: Give the pre-test, p. 8.

II. Study of squid anatomy - structure and function

A. Field work: You can either purchase squid specimens from a biological supply house or collect them yourself, using the following procedure:

At Indian River Inlet after dark, suspend a gas lantern about two feet above the surface of the water. This can be done by hanging the lantern from the end of a long pole. At five-minute intervals, gradually reduce the light's brightness until the radius of the circle of light is about two feet. Many light streaks will appear as the squid move back and forth through the circle of light. The squid will be attracted to the spot because large numbers of minnows will be attracted to the light. With a long-handled, very fine-meshed dip net, dip up the squid as they dart back and forth in the light.

B. Classroom procedure: dissection of the squid

1. Hand out dissection kits and dissecting pans. Either fresh squid or preserved specimens may be used. The parts of the anatomy may be more easily recognized in a preserved specimen because the formaldehyde will harden the viscera.

2. Show the transparency of the squid's anatomy on p. 18. Hand out copies of the transparency on p. 18.

3. Hand out copies of the instruction sheets for squid dissection (p. 10) and have the students begin the dissection. Move through the classroom, aiding students who have trouble.

C. As a post-test, give the following laboratory practical:

Have squid specimens dissected and pinned open. Insert pins with numbered tags attached into different parts of the body. At each specimen station ask for identification of the part and/or function. For example, at one station a pin will be inserted in the pen accompanied by a file card on which the following appears: (1) Name the structure, (2) What is its function? Alternately, the use of the dissected specimens can be omitted and a diagram without labels used to test students' knowledge of anatomy. (see p. 19)

D. Optional Activity. MOLLUSK CROSSWORDS (See p. 12-14.)
For group fun or an extra-credit assignment.

Comparing Clam and Squid

Class discussion:

A. The clam and squid are members of two different classes of the Phylum Mollusca. What characteristics do they have in common?

1. Bilateral symmetry
2. Both have a foot although the functions differ.
   a. Clam - locomotion
   b. Squid - grasping and holding prey
3. Both have a type of shell.
   a. Clam - a 2-valve calcium carbonate shell
   b. Squid - the stiff, plastic-like pen
4. Both have a space between the main body and the mantle called the mantle cavity.
5. In both the anus opens into the mantle cavity.

The latter two common characteristics will be difficult for the class to develop. Perhaps special individual or group library research assignments would be appropriate here.

B. Compare the organs and body systems studied in the dissections, e.g. the digestive systems or the reproductive systems.

C. Contrast the methods of locomotion in some detail.

Pre-test (clam)

1. Clams move by _____ A.) swimming B.) opening and closing their shells C.) pulling themselves through the sand.

2. Clam shells have ____ parts. A.) 1 B.) 2 C.) 3

3. A clam moves by means of a _____ A.) foot B.) tongue C.) hinge.

4. A clam moves through the sand with its shell hinge _____ A.) up B.) down C.) neither A nor B

Answers to Pre-test (Clam)

1. C
2. B
3. A
4. A

Answers to Post-test (Clam)

1. foot
2. two
3. digestive
4. gills
5. blood fills a cavity
6. answers will vary according to method of administering lab practical

Answers to Pre-test (Squid)

1. yes
2. jet propulsion
3. ink screen and the ability to change color
4. ten
5. suckers
6. backward
7. yes, very well
8. cigar or torpedo-shaped

Post-test (clam)

1. The clam's major organ of locomotion is the _____.
2. A clam has _____ (number) muscle(s) that close(s) the shell.
3. The green gland of the clam belongs to what body system? _____
4. The major organs of respiration in the clam are the _____.
5. The clam's foot swells to act as an anchor. What causes it to swell? _____
6. Identify the pinned and tagged parts of the clam's anatomy.

Pre-test (squid)

1. Does a squid have a form of shell?
2. What do you call the type of locomotion used by the squid?
3. What are the major means of protection used by the squid?
4. How many appendages does a squid have?
5. What is found on the squid's arms that allow it to hold on to its prey?
6. In which direction would a squid move fastest--forward or backward?
7. Can a squid see?
8. How would you describe the shape of the squid's body?

Dissection of Clam

Materials needed: Freshwater clam, dissection tray, knife, scalpel, scissors, forceps, dissection needles

Procedure: First, observe that the clam shell is made up two valves. These valves are hinged together on one side of the clam, but can open along the other margin. When the shell is closed, the valves are held together by two powerful muscles at opposite ends of the clam and fairly close to the hinge line. Your teacher will open the clam by inserting a knife between the valves and cutting these two muscles.

1. Locate the thin mantle layer on the inner surface of each valve. It is this layer which develops the shell and coats any pearl that may be formed. Attached to the inside of the valves you can see the cut ends of the two muscles that contract to close the shell.

2. Remove the mantle layer from a part of one valve. Note the smooth, fine-grained inner surface of this valve. See if it is the same color all over its surface. This shell lining is called mother-of-pearl.

3. Find the two siphons extending out from one side of the clam's body. Water enters the mantle cavity through one siphon and passes out through the other siphon.

4. Note the muscular structure known as the foot, which makes up a large part of the body mass. In life it extends out through the mantle layer. It is used to slowly move the clam along the bottom of a stream.

5. Examine the gills that lie on either side of the foot in the mantle cavity.

6. Cut open the body mass. Find the heart, the stomach, and the intestine.

Dissection of Squid

1. External view

   a. Locate the eight arms and the two tentacles, or grasping arms found on the head. The foot of the squid consists of these ten arms, used for grasping prey and holding it to the mouth. Notice the suckers. These work like rubber suction cups on the end of a toy arrow. The squid can release them at will by muscles that pull up the center part of the disk.

   b. Separate the arms to find the mouth in the center. Look for an opening; insert a probe and find the jaws.

   c. Eyes

   d. Locate the siphon beside the head. It looks like a tube.

   e. Look at the collar region which surrounds the neck. This is really part of the mantle. The collar muscles expand to let water into the body cavity, and then contract when the cavity is full. The muscle in the mantle then contracts and the only opening for the water to pass through is the siphon. This resembles a fire hose containing water under high pressure. As the water shoots out the siphon, the squid shoots through the water, jet propelled. Notice that the siphon may be moved in any direction to direct the path of the squid.

   f. At the back or posterior end of the squid find the two fins which stick out from the cigar-shaped body. These help to stabilize the squid as it moves through the water. The fins also act as a guide for the sudden turns that a squid often makes.

2. Internal view

   a. With the squid held in your left hand locate the siphon. Now with a pair of scissors make a cut just to the side of the siphon from the collar to the posterior end passing between the fins.

   b. Locate the pen. It is stiff and plastic-like. This allows the soft-bodied squid to move through the water without collapsing.

   c. Locate the muscles which are attached to the siphon. Notice that the siphon is movable.

   d. Digestive system. From the head, follow the tube leading down the body. This is the esophagus. The tube becomes a bag or sac; this is the stomach and below it is the cecum. The stomach is the primary site of digestion and the cecum helps by increasing the size of the digestive area. The tube turns upward; this section is intestine which ends at the anus. The anus is the external opening at the end of digestive system, and through it wastes are eliminated. The anus is close to the siphon.

   e. Find the gills. These are feather-like in appearance and transfer oxygen from the water to the blood and carbon dioxide from the blood to the water.

f. At the posterior end of the squid's body cavity you will find the gonads. These are the reproductive organs. When the sex of the animal is unknown, these organs are called gonads, which would be ovary (female) or testes (male). Notice the tube leading away from the gonads toward the siphon. This is the gonaduct through which the sex cells pass. Fertilization is internal in the squid. The male produces a sperm package, and with one of his tentacles, which is modified into a copulatory organ, he reaches into his body cavity and takes out a package with his tentacle suction cups. He places this sperm package into the body cavity of the female where the eggs are fertilized and laid in strings from rocks or on water vegetation. They are hatched later in the summer.

g. Look centrally in the body cavity for the ink sac. It is black in color and has a tube leading toward the siphon. The ink is used to put out a decoy shaped like a squid. This attracts the attention of the squid's enemy as the squid changes its color to almost transparent and jets away to safety.

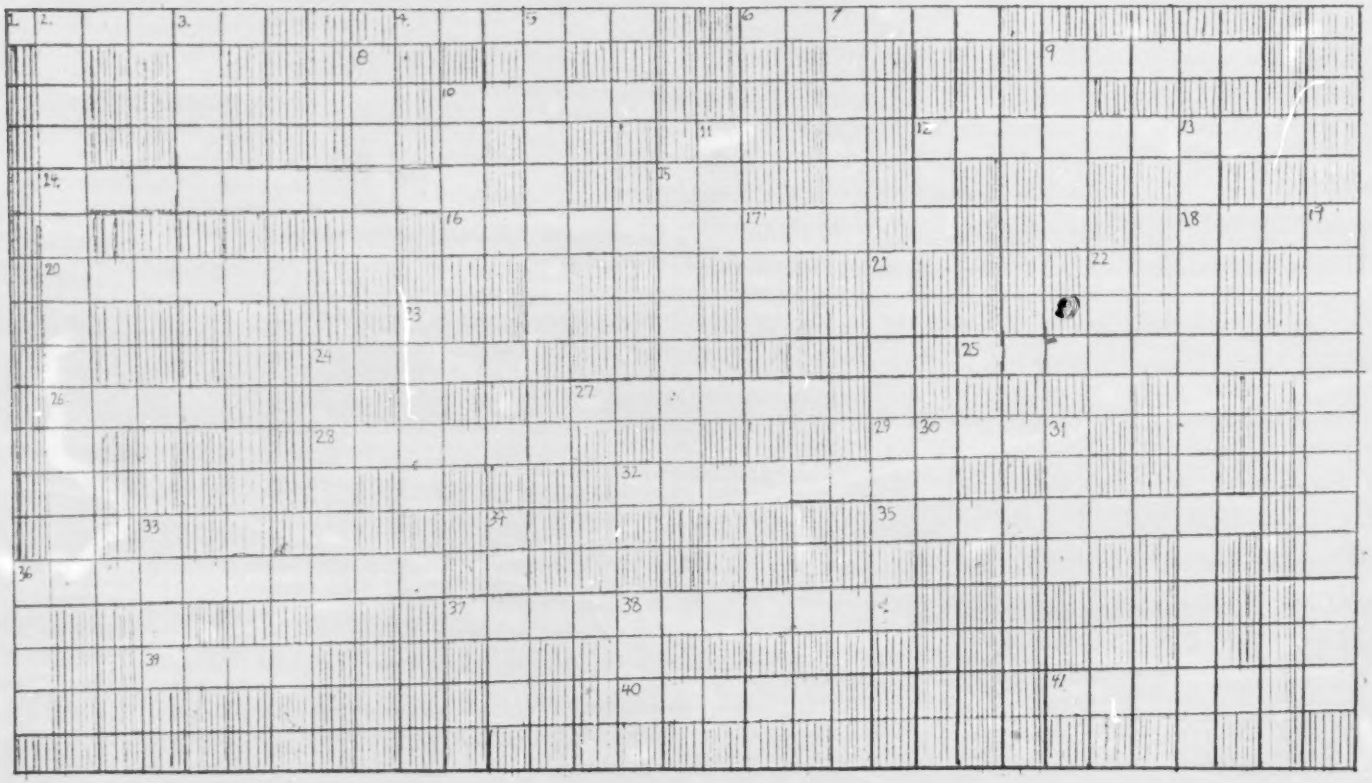
ACROSS

1. Part of clam which makes the shell.
4. Mollusk with shell divided into eight transverse plates.
6. Attach.
9. Spiral shelled mollusk found on land, salt and fresh water.
10. Reproductive organ, when sex is unknown.
12. Green gland of clam belongs to this system.
14. Muscles attached to clam shell when contracted will_____ _____.
15. I.
16. What foot of clam is used for.
18. Common bivalve.
20. Sessile bivalve.
24. Torpedo-shaped mollusk with tentacles.
25. Waste leaves clam through _____ siphon.
26. Oldest part of clam shell.
27. Often found attached to rocks in the bay. The Blue _____.
28. The swollen foot of a clam functions as an _____.
29. Gem found in and made by bivalves.
32. Squid-like mollusk that also has an external shell.
35. Organ of balance.
36. Class which clam is in.
37. Class which squid is in.
39. Not let go.
40. Opens clam shell.
41. Liquid which rushes into cavity in clam's foot to swell the end.

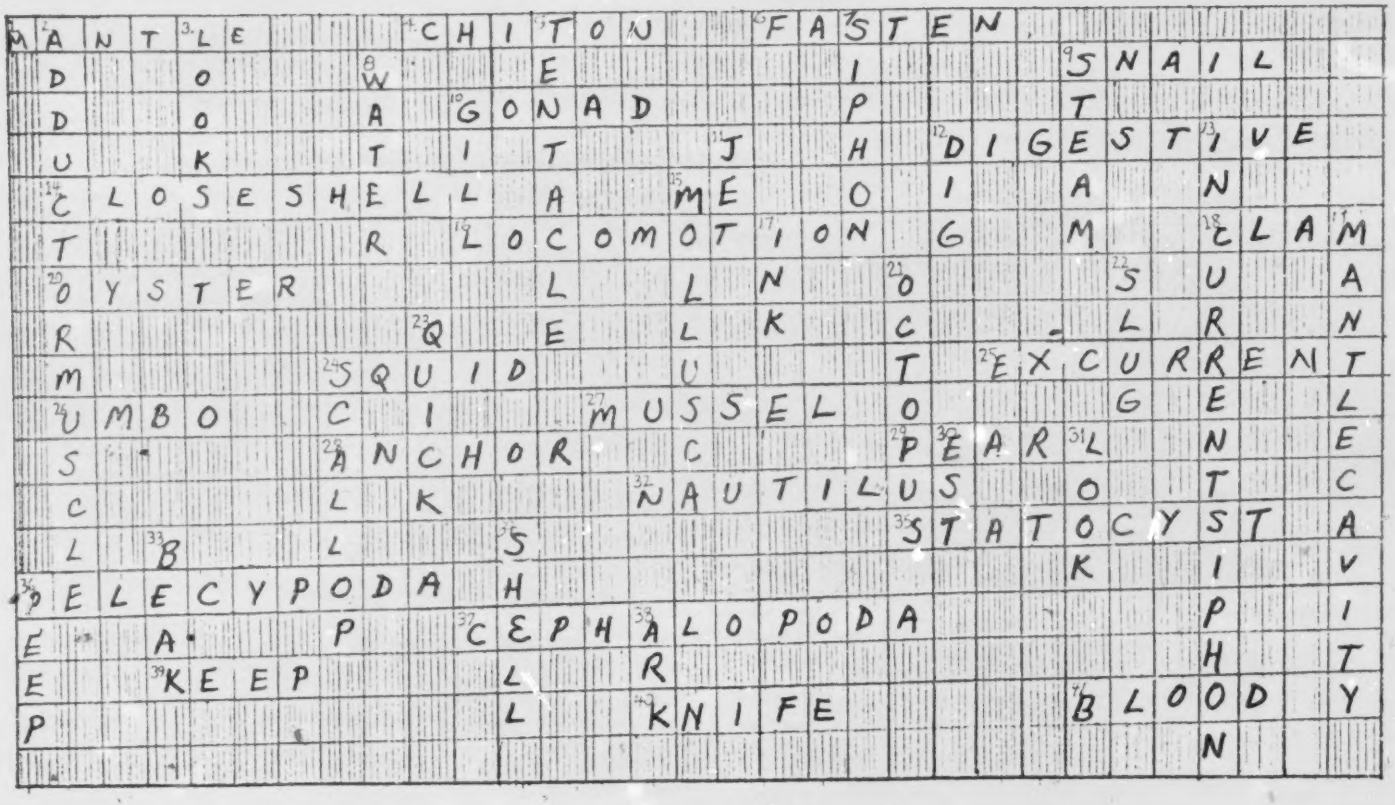
DOWN

2. This closes the clam shells.
3. Sees.
5. Appendages of squid.
7. Directs water flow out of the squid.
8. Most mollusks live in it.
9. Used to cook clams.
10. Organ of respiration for clam and squid.
11. Type of propulsion used by squid.
12. Way to get clams.
13. Water enters clam through _____ _____.
15. Phylum to which clam, squid, octopus, mussel belong.
17. Defense liquid of squid.
19. The space between the right and left lobes of the mantle and surrounding the body of the clam.
21. Bag-shaped cephalopod with eight arms.
22. Shell-less member of gastropods.
23. Fast.
24. Bivalve which moves by clapping shells together.
30. Abbreviation for estimate.
31. Stop, _____, and listen.
33. Jaws of squid look like a _____.
34. Used to make mother-of-pearl buttons.
36. Sound made by baby chick.
38. Type of boat.

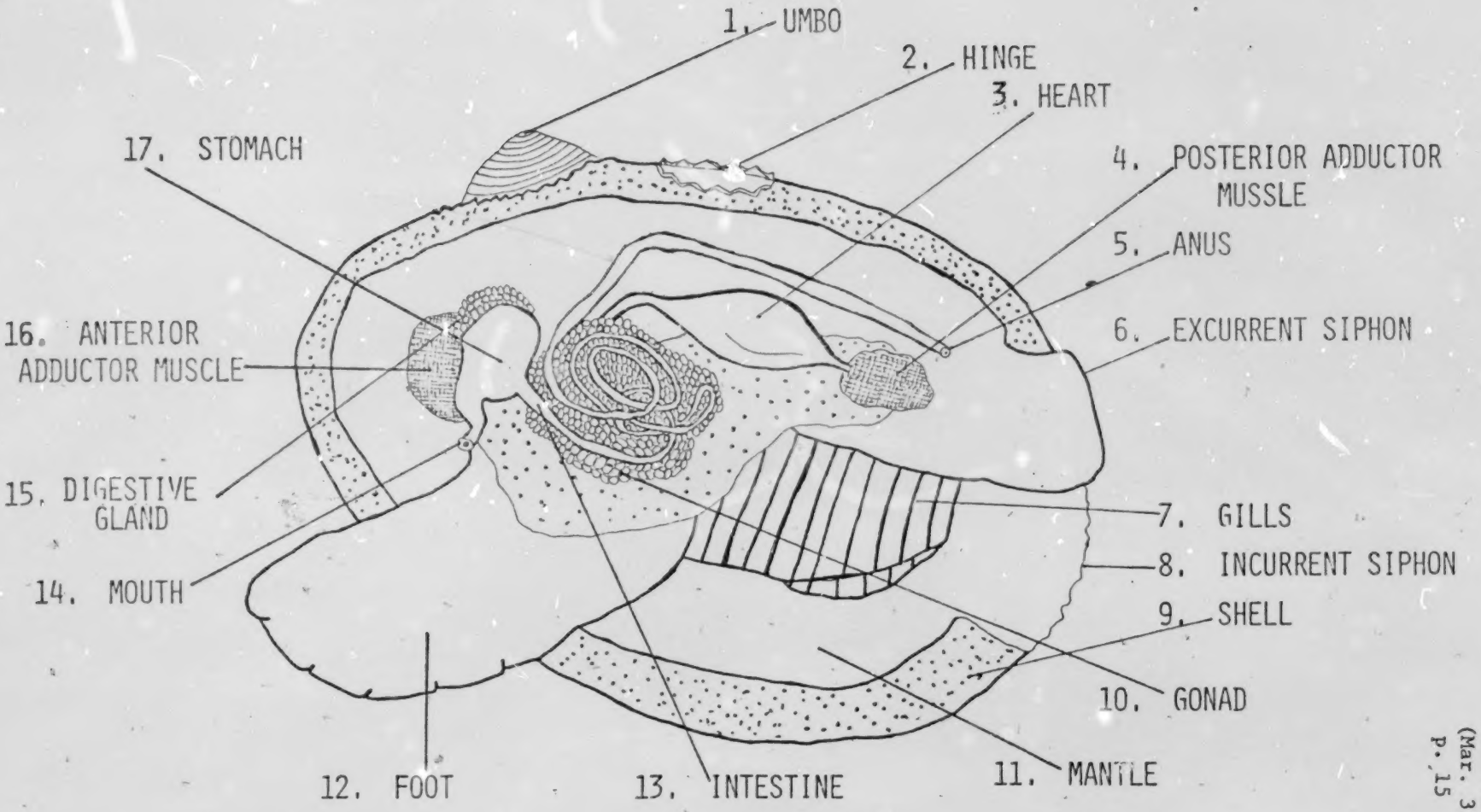
MOLLUSK CROSSWORDS



MOLLUSK CROSSWORDS--Key



CLAM ANATOMY



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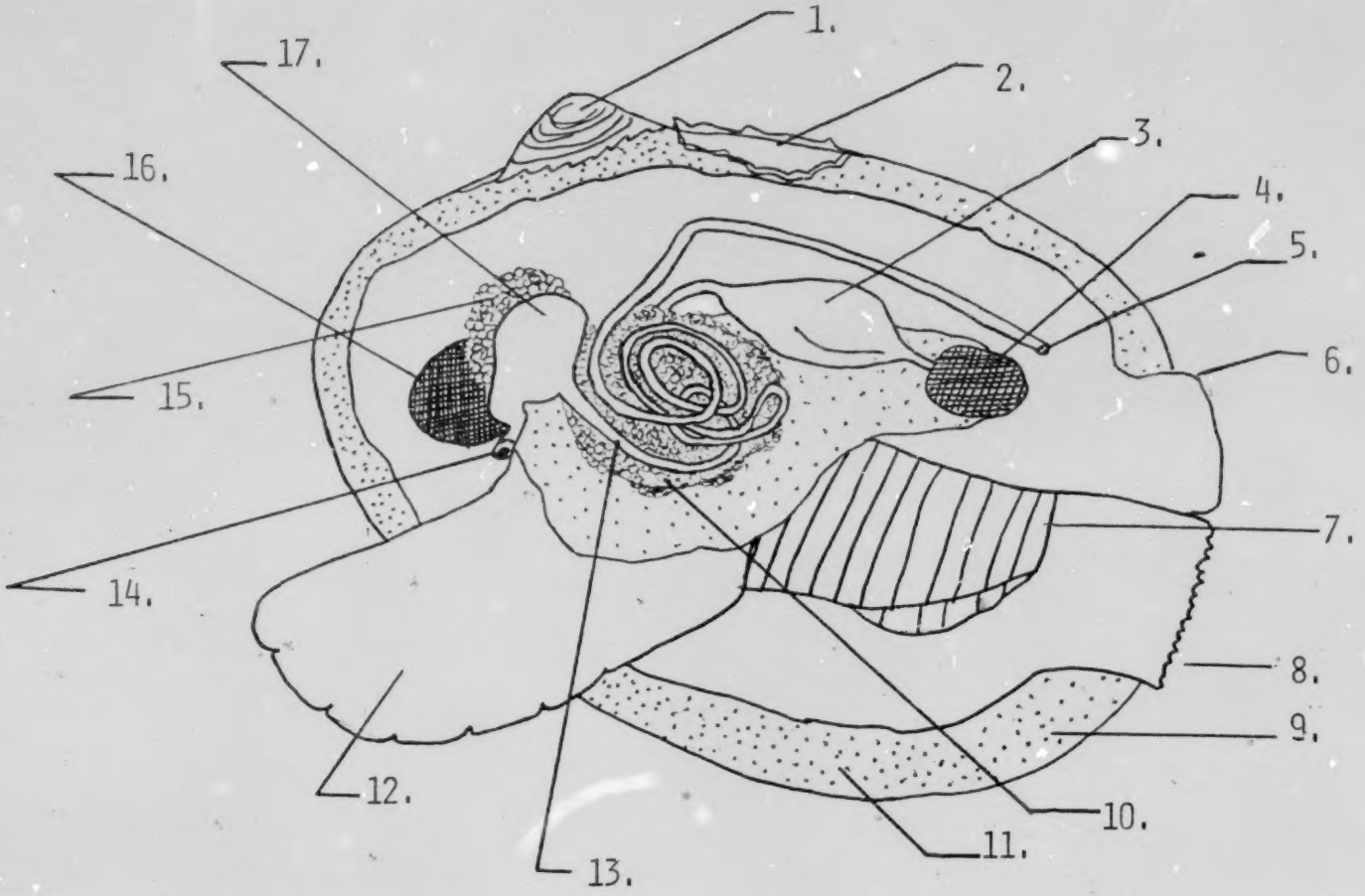
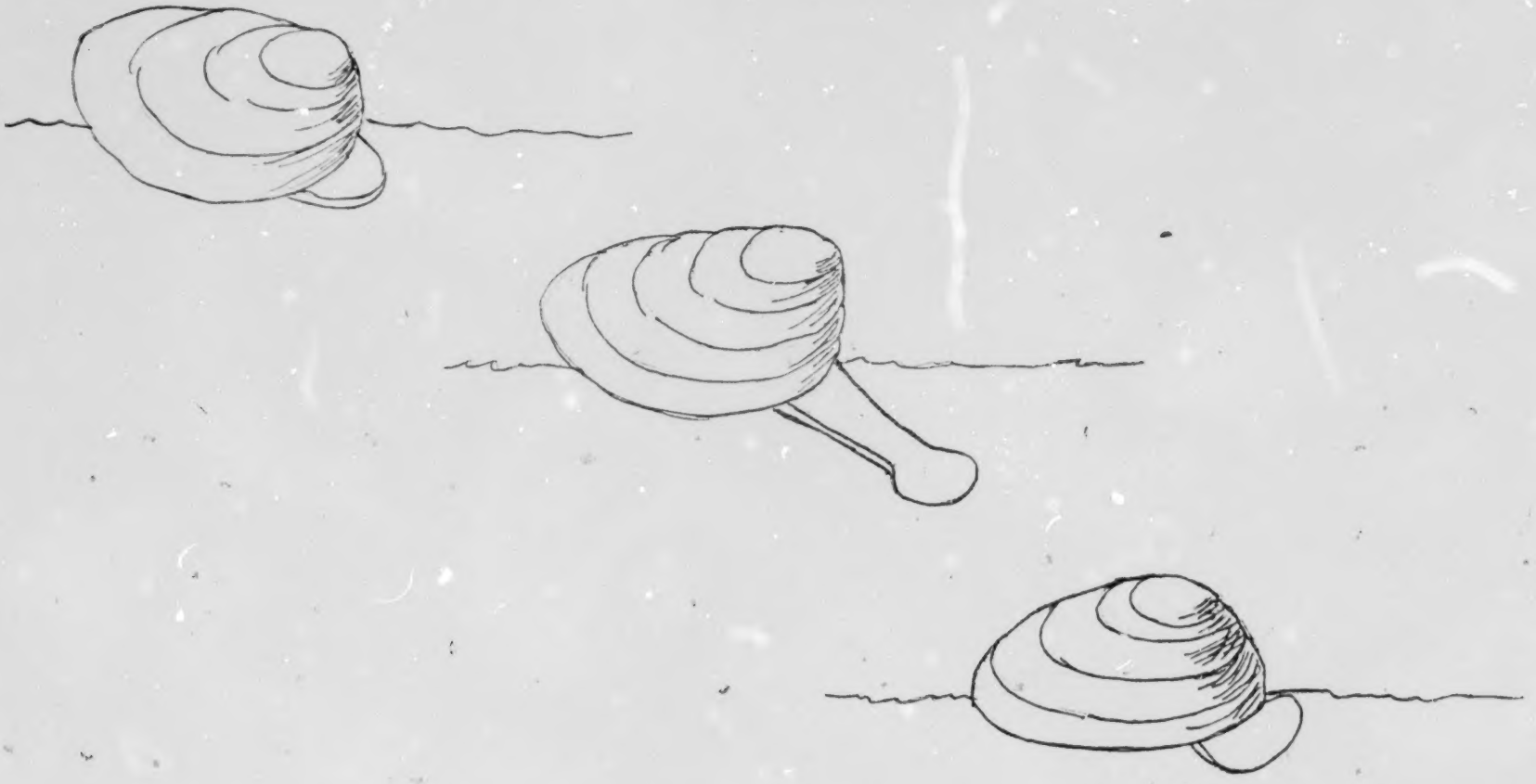


CLAM LOCOMOTION



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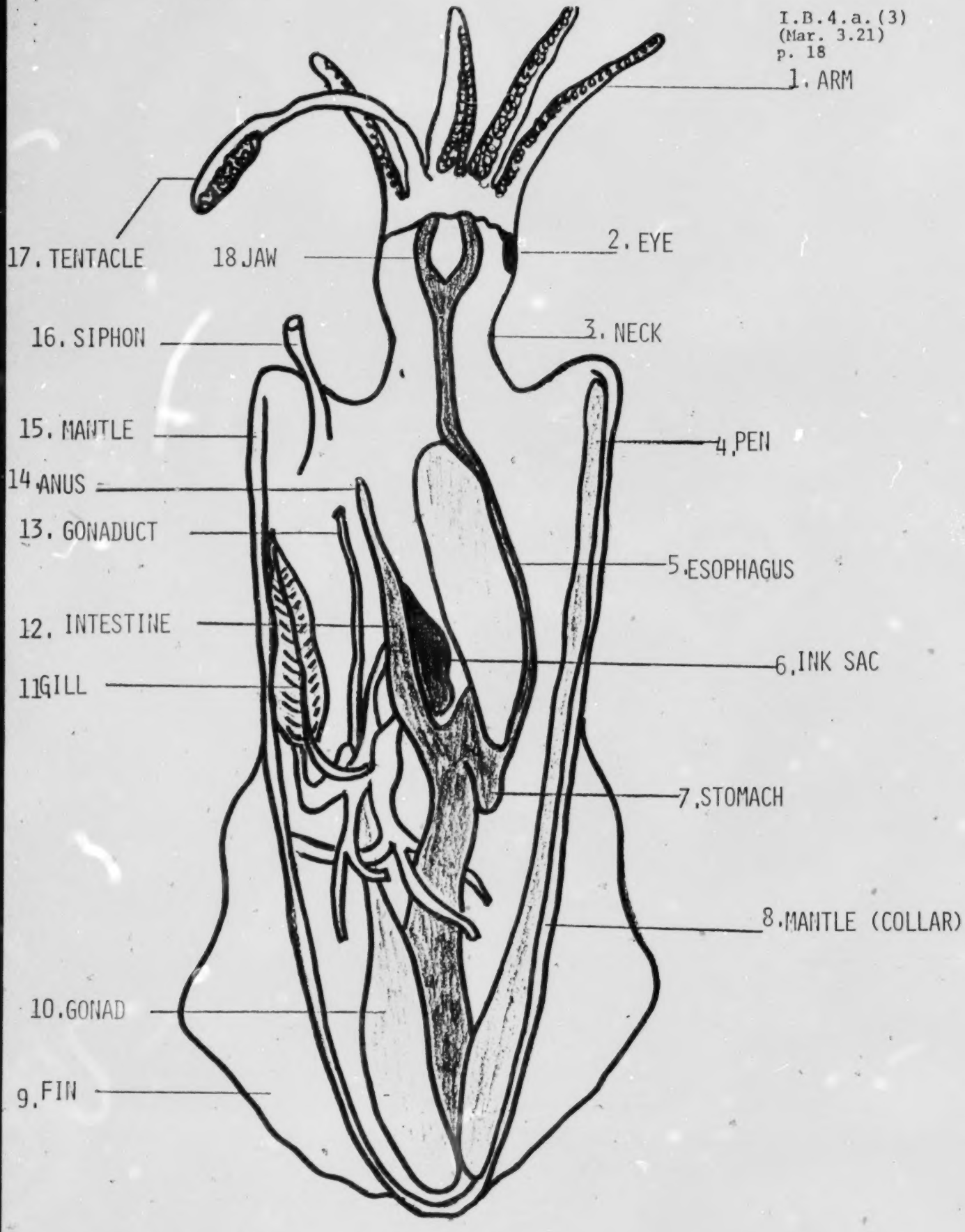
1. ARM
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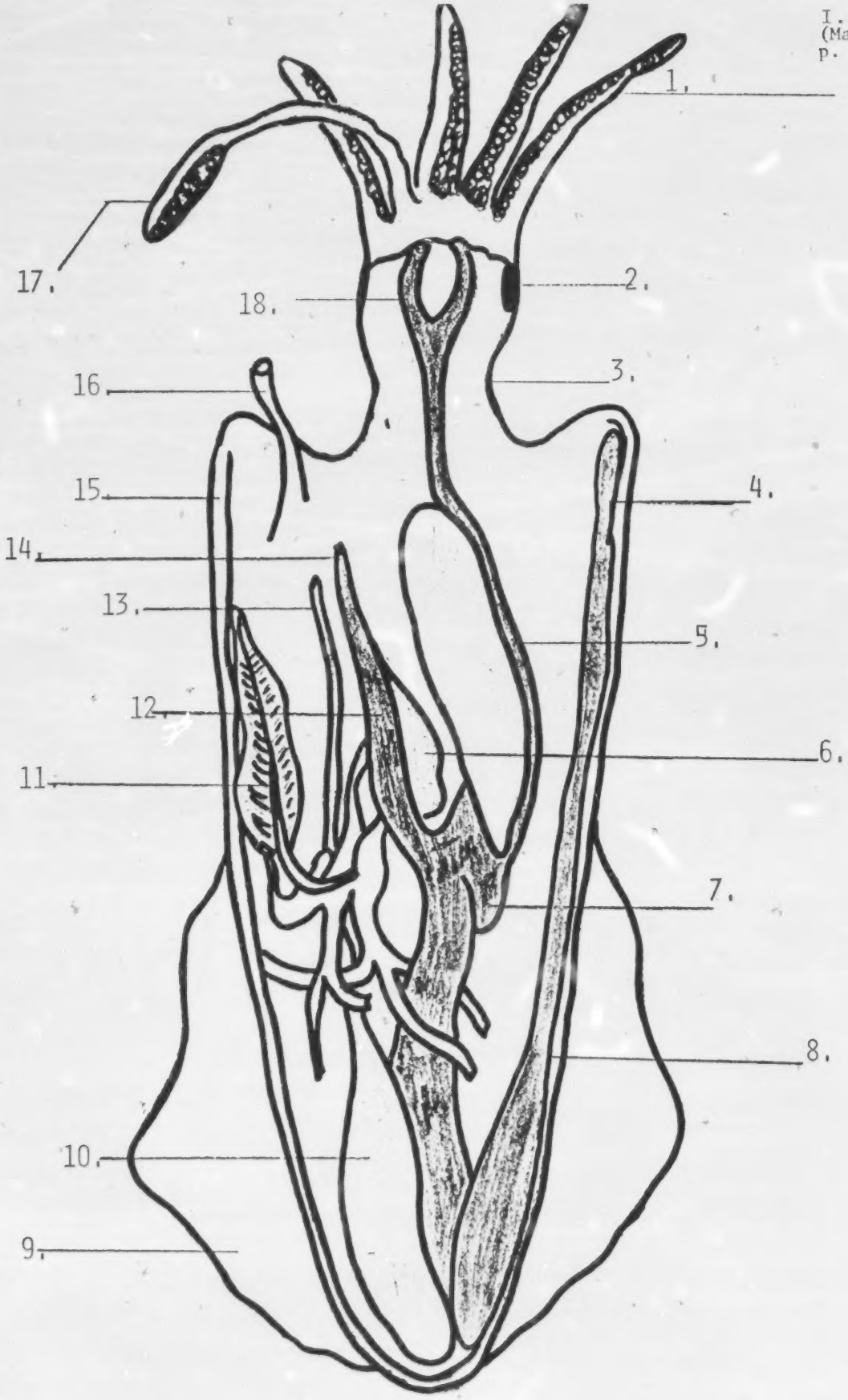
3. NECK
4. PEN
5. ESOPHAGUS
6. INK SAC
7. STOMACH
8. MANTLE (COLLAR)
9. FIN
10. GONAD
11. GILL
12. INTESTINE
13. GONADUCT
14. ANUS
15. MANTLE
16. SIPHON
17. TENTACLE
18. JAW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BITING FLIES OF THE COASTAL REGION

A Learning Experience for
Coastal and Oceanic
Awareness Studies

Produced by

MARINE ENVIRONMENT CURRICULUM STUDY
MARINE ADVISORY SERVICE
UNIVERSITY OF DELAWARE

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DEPARTMENT OF PUBLIC INSTRUCTION

DEL MOD SYSTEM

DUPONT EDUCATIONAL AID COMMITTEE

TITLE: BITING FLIES OF THE COASTAL REGION

* CONCEPT: VI.A.3.a.

VI. By planning within the natural system, a life of acceptable quality can be provided for all people.

A. Individual values and life styles can be compatible with a permanently hospitable and beautiful planet.

3. Individual concern can lead to the enhancement of the esthetic qualities of the environment.

a. RESPECT FOR THE NATURAL SYSTEM COULD ENSURE THE SURVIVAL OF NATURAL AREAS.

** MARINE CONCEPT: 3.21

3. Marine organisms interact in complex ecosystems.

3.2 Marine organisms are adapted to their environments in different ways.

3.21 Marine organisms are adapted developmentally, structurally, functionally, and behaviorally to their environments.

GRADE LEVEL: 7-10

SUBJECTS: Science, Biology

CLASS PERIODS: 3-4

AUTHOR: Levitan

* From A Conceptual Scheme for Population-Environment Studies, 1973. Cost $2.50.

** From Marine Environment Proposed Conceptual Scheme, 1973. No charge.

Both conceptual schemes are available from Robert W. Stegner, Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

TEACHER BACKGROUND

Biting flies pose a tremendous problem to man and animals as direct and indirect agents of disease and discomfort. This is especially true in coastal and estuarine areas since these pests usually breed in marsh regions. This learning experience uses the inquiry approach to enable students to:

1. Define the various hazards of biting flies.
2. Identify the biting flies of the middle Atlantic coastal region.
3. Describe the flies' life cycles.
4. Describe the mechanisms these flies have for biting.
5. Develop pest control methods.

The inquiry method utilizes questions posed by the teacher, graphs, illustrations and readings to enable students to accomplish these objectives.

Students may not be able to answer some of the questions. Rather than offer the answer, the teacher should at first repeat or rephrase the question to suit the level of the class. The teacher may guide the discussion to develop a wrong answer into a correct one. Students who offer wrong answers should not be "put down" but errors should not persist at the end of the inquiry. A post-test is provided as a final check.

Since this learning unit has been devised for grades 7-10, some questions may not apply to a particular grade level. However, most answers are divided into two sections. Those denoted by S are short, basic explanations, while those denoted by D are more detailed, involved answers. Therefore, it is up to the teacher to decide which answers should be used.

QUESTIONS AND DISCUSSION

1. T: In August 1972, a survey was made in three coastal counties of North Carolina to determine the public's opinion of biting flies. Figure 1 (p. 3) illustrates some of the answers to the survey questions. From the graph and chart, what can you conclude about the effect of flies on coastal populations?

   S: Biting flies interfere with outdoor activities during the summer months.

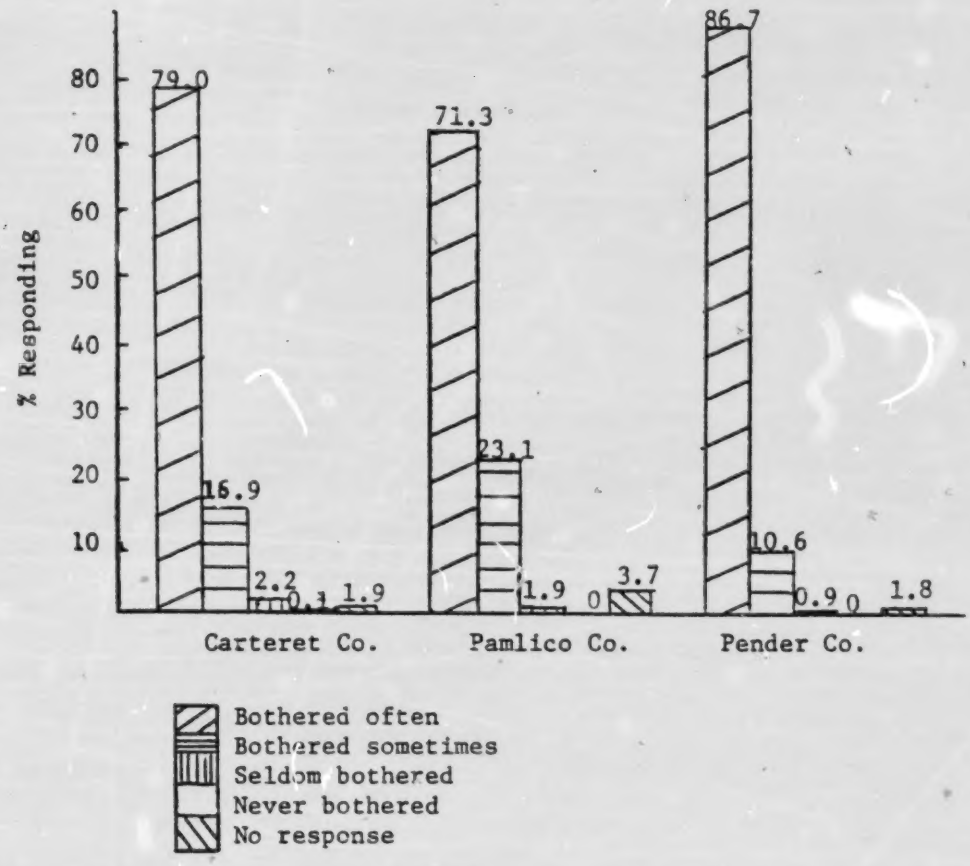
2. T: Mathematics Exercise (refer to Fig. 1, p.3): If 903 from Carteret County, 160 people from Pamlico County and 113 people from Pender County responded to the survey, how many people in each county were bothered often, bothered sometimes, seldom bothered, or never bothered by biting flies?

   S:

Counties	Bothered Often	Bothered Sometimes	Bothered Seldom	Bothered Never
Carteret	713	153	20	1
Pamlico	114	37	3	0
Pender	98	12	1	0

FIGURE 1

Question 1: How often are you bothered by biting insects out-of-doors?



Question 2: Do biting insects interfere with any of the following activities in which you participate?

	% YES			% NO		
Activity	Carteret	Pamlico	Pender	Carteret	Pamlico	Pender
Yardwork	96.1	93.4	99.1	3.9	6.6	0.9
Golf	72.7	71.4	64.3	27.3	28.6	35.7
Fishing	88.4	89.1	96.8	11.6	10.9	3.2
Hunting	87.8	92.3	95.7	12.2	7.7	4.3
Swimming	76.5	65.1	83.5	23.5	34.9	16.5
Boating	79.2	63.9	93.7	20.8	24.0	6.3

(Gerhardt et al., 1973)

3. T: What experiences have you had with biting flies and where did they take place?

   S: Answers should emphasize the annoying and sometimes painful bites of these flies. The question is designed to involve students in the subject matter and provide personal experiences with which to relate.

4. T: What other ways do insects affect human and animal health? (It may be advantageous for the teacher to list some or all of the effects on the board.)

   S: Insects are direct and indirect agents of disease and discomfort. (James & Harwood, 1969, pp. 9-10).

   D: As direct agents:

   1. Annoyance - by buzzing, swarming, biting, settling on the body, interfering with daily activities, destroying food, clothing, and woodwork.

   2. Blood loss - many insects feed by sucking blood. Although not a problem for humans, blood loss reduces the production of individual livestock and can result in death.

   3. Accidental injury to sensory organs - accidentally entering ears, eyes or nose causing irritation.

   4. Skin irritation - bites by mosquitoes or skin-burrowing insects, such as ticks or mites.

   5. Envenomization - venom introduced by an insect as a result of a bite or sting.

   6. Allergic reactions - people may be very sensitive to insect bites and stings and exhibit allergic responses.

   7. Infestation of organs and tissues by maggots - known as myiasis.

   8. Entomophobia - a psychological fear of insects, usually accompanied by the belief that insects are present when they actually are not.

   As indirect agents:

   Insects act as vectors; they are capable of transmitting other organisms such as protozoa, bacteria, viruses and worms that cause diseases. Transmission may be accomplished as a result of the insect swallowing or picking up on its body the disease-causing agent from an infected organism or feces. The pathogen is not usually harmful to the insect. It is then passed onto a healthy organism through insect bites, contact, or through insect feces. (Busvine, 1966, pp. 1-5).

5. T: What are some of the common biting flies of the coastal marsh and beach regions? (Figures 3 and 4, pp. 18-19)

S: Mosquito - salt marsh mosquito (Aedes sollicitans)
Tabanid Flies - salt marsh greenhead (Tabanus nigrovitattus)
- yellow deerfly, also known as sheepfly (Chrysops atlanticus)
Stable Fly - also known as biting house fly (Stomoxys calcitrans)
Simuliid Flies - black fly (Simulium sp.)
Biting Midges - punkies, "no-see-ums" (Culicoides sp.)

6. T: Why are these biting flies common in coastal marsh regions?

S: The biting flies mentioned above breed in coastal aquatic environments and their eggs require wet surroundings (moist soil or water) to develop. When the eggs hatch, the new flies tend to remain in the coastal region.

D: At this point it may be interesting to investigate the breeding habits and egg development of the biting flies. There are four stages:

1. fertilization and egg deposition
2. larval development
3. pupal development
4. adult stage (Barnes, 1968, p. 537)

While in flight, the male deposits his sperm into the female's reproductive organs where they are stored until the eggs are laid. As the female lays her eggs, they become fertilized by the stored sperm. The egg undergoes cleavage and develops into a larva which appears when the egg hatches. The larva has no wings and no similarity to the adult fly, but is an active feeder. Its feeding habits usually differ from the adult's. During this stage and the following pupal stage, the underdeveloped fly molts; it sheds its external skeleton, increases in size and develops a new skeleton.

At the end of the larval period when food reserves have been built up, the young become non-feeding and quiet. This is the pupal stage and is usually spent in a protective place such as in a cocoon or in a burrow in the ground. During this period, adult structures develop. At the end of the pupal stage, the adult emerges.

Salt Marsh Mosquito

The salt marsh mosquito breeds in the aquatic environment. The adults are capable of producing many generations of young during a summer. The females lay the eggs on the moist marsh soil. Larval hatching occurs as a result of tidal flooding or rainfall. The larvae (see Fig. 2, p. 17) live in brackish water, near the surface. They breathe atmospheric air through tube-like projections which penetrate the water surface from one of the body segments. The larval head contains groups of bristles around the mouth which direct water currents into the mouth. Food particles are filtered out by other bristles (Busvine, 1966, pp. 192-3).

After four larval molts, pupae form. Like the larvae, the pupae remain at the water surface to breathe but, unlike the larvae, they cease feeding. Traces of wings and long legs are seen and in the center, a large air cavity forms to add buoyancy. The pupae then develop into free flying adults (Busvine, 1966, pp. 193-4).

Tabanid Fly

The tabanid flies deposit their eggs on plant leaves or rocks in or adjacent to water or marshes--especially where there is slow-moving water. The larvae hatch from the eggs and drop into the mud or wet soil along the edge of the marsh (see Fig. 2, p. 17) The larvae have air tubes through which they breathe in their hind ends. They also have fleshy appendages along their sides which allow them to move through the soil (Oldroyd, 1965, p. 102). The pupae also live in the mud around the margins of the marsh and show similarities to the adult.

Stable Fly

The stable flies lay eggs in manure, rotting vegetation in the salt marsh, or in seaweed washed up on the beach (Lake, 1973, p. 43). The larvae (see Fig. 2 , p. 17) are maggot-like and feed on vegetation (Snow, 1974, p. 58). The pupae leave the breeding area for a dry zone where they eventually develop into adults (Bosvine, 1966, p. 216).

Black Fly

The black flies breed exclusively in rapid freshwater streams. The eggs are deposited on leaves of aquatic plants, twigs, and submerged stones (Busvine, 1966, p. 209). Due to their respiratory organs, the larvae (see Fig. 2, p. 17) require well-aerated water such as water in moving streams or water which contains air bubbles from plants (Oldroyd, 1965, pp. 68-69). The larvae use hooks from their hind ends to attach to rocks or plants and hang downstream. The mouth contains bristles which trap food particles carried by the current. The larvae form immobile cocoons in which the pupae develop (Busvine, 1966, p. 209).

Punkie

The breeding sites of the punkie are in salt water, freshwater streams, stagnant water, mud or humus (Busvine, 1966, p. 206). The larvae develop in these environments and have a retractable hind segment which contains gills for breathing and spines for anchoring (Snow, 1974, p. 39). The pupae develop respiratory organs to breathe atmospheric air. They must rise to the surface occasionally to breathe, but still maintain the spines for anchoring.

7. T: When are the adult biting flies most bothersome? Why?

S: Biting flies are most bothersome at various times during the spring and summer because it is at these times that the adult biting flies swarm together to live, feed, and breed. The biting flies' individual life habits determine when, during the course of a day, they are most bothersome.

D: The stable fly develops from the egg to the adult in 21 to 25 days (Lake, 1973, p. 43). By the end of the summer, they become most abundant and thus most bothersome along the beaches. They are active only in daylight (Catts, 1973, p. 12).

The two tabanid flies, the yellow deer fly and the salt marsh greenhead, are pests throughout the summer in the daylight hours (Lake, 1973, pp. 39-40).

The salt marsh mosquito is the major biting fly pest. It bites both day and night throughout the summer and ranges far inland (Lake, 1973, p. 38).

The punkies are present throughout the spring and summer. However, peak populations in Delaware have been recorded from May through early June and again in August. They are most annoying during twilight hours when there is little wind because they are unable to fly in breezes stronger than three miles per hour (Lake, 1973, p. 42).

Evident throughout the summer, the black flies are especially active during the daytime and sometimes in the evening.

8. T: In the coastal regions of the United States, what makes these biting flies so bothersome?

S: As their name implies, they are bothersome because of their annoying bites.

9. T: For what reason do these flies bite?

S: Flies bite to feed upon the blood of other organisms. In all species of the biting flies mentioned except the stable fly, only the female bites. The reason for this is that the protein contained in the blood is essential for egg production (Busvine, 1966, p. 185).

10. T: What mechanisms do these flies use in feeding?

S: Insects have various feeding apparatus. Their mouthparts have become adapted to an individual genus' mode of feeding. Some insects such as cockroaches have toothed, jaw-like mouthparts which enable them to chew. Others such as the house fly have pads for licking. Bloodfeeding flies, however, have piercing mouthparts to penetrate skin and tissue (James and Harwood, 1969, p. 24).

D: In bloodsucking biting flies, the mouthparts consist of a projection from the head. Ensheathed in this projection are the actual organs used in piercing, known as stylets. The males of all fly species mentioned in this unit, except the stable fly, have reduced or weakened piercing parts because they do not feed upon blood.

The mosquito (see Fig. 5, p. 20) has six stylets which are loosely ensheathed in the surrounding projection or labium (James and Harwood, 1969, p. 26). Two of the stylets have saw-like tips which lacerate the tissue while another two are needle-like and aid in breaking the skin. As the six stylets penetrate into the skin, the labium remains on the surface of the skin in contact with the stylets to act as a guide (Snow, 1974, p. 24) (see Fig. 5, p. 20) The mosquito then feeds from a blood vessel.

The punkies have a similar feeding mechanism and structure to the mosquitoes, although the mouthparts of the punkies are shorter (Busvine, 1966, p. 207).

The black flies and tabanid flies have similar feeding apparatus (see Fig. 5, p. 20) They consist of six short blade-like stylets, four of which are used in piercing and cutting. Two of the stylets move in a scissor-like motion to cut the skin. The other two stylets move in and out to enlarge the wound. In this manner, blood vessels are ruptured and the fly feeds upon the pool of blood which is formed in the tissue (James and Harwood, 1969, pp. 26, 31).

The stable fly is the only species of biting flies in which both the female and male are bloodfeeders. Its mouthparts are very specialized for feeding with the stylets reduced to two in number, both closely ensheathed in the labium (Fig. 5, p. 20) There is a muscular bend in the bayonet-like feeding projection. The stable fly penetrates the skin with a thrust of the head and body. These flies also feed upon the blood in the tissue from broken blood vessels (James and Harwood, 1969, pp. 26, 32).

11. T: <u>At this time, it may be beneficial to review when, where and why biting flies are bothersome</u>.

S: When: During the late spring and summer when they are actively breeding, swarming and feeding.

Where: In coastal regions since the pre-adult stages of the biting flies require damp regions or water in which to develop.

Why: There are many reasons, but the most important ones in the United States are annoyance through biting, buzzing, and swarming, livestock blood loss and transmission of disease.

12. T: In the North Carolina survey, the question was asked: Do you think there should be more community effort devoted to the control of biting insects in this area? The following responses were categorized:

County	Need More	Need Less	Adequate Now	No Opinion	No Response
Carteret	84.2%	1.6%	6.3%	5.4%	2.4%
Pamlico	72.5%	1.3%	10.0%	12.5%	3.8%
Pender	86.7%	0.9%	4.4%	4.4%	3.5%

What can you assume from the above results?

S: An overwhelming majority of people found biting flies bothersome enough to warrant additional control measures to reduce the numbers of these pests.

13. T: How would you (the student) try to control biting flies?

S: This question is designed to draw from the students' previous knowledge of how insects are controlled. Have the students name as many methods as possible. List these as well as others they have not mentioned in the following manner on the chalkboard.

Personal Protection	Environmental Changes	Biological Control
Screens	Drainage ditches	Parasites
Repellents	Marsh flooding, filling	Predators
		Disease-causing organisms

Insecticides	Traps	Reproductive Manipulation
Source treatment (aimed at immature forms)		
Adult treatment		

14. T: Insecticides, also known as pesticides, are chemicals which are poisonous to insects. Since adults are able to fly and thus spread over wide areas, it is sometimes more efficient to apply the insecticide to the breeding areas, such as a marsh, where the larvae and pupae develop. However, if the adult is known to reside in a particular area, insecticides aimed at that life stage are also an efficient means of insect control.

What are some of the advantages and disadvantages of insecticides?

S: Advantages:

1. Effective in killing biting flies
2. Can easily be applied over large areas (by cropdusters, for example)

Disadvantages:

1. They may be poisonous not only to insects but also to fish, birds, livestock and humans.

15. T: How would the life cycle of the biting flies be affected by draining, flooding or landfilling the marshes?

S: Draining or landfilling the marshes would ruin the moist or wet conditions needed for larval and pupal development, thus destroying the biting fly breeding places. Flooding would destroy the breeding areas where moist soil is required. It would also kill those larvae unable to live in high salinity waters.

16. T: For each of the species discussed, how effective would these environmental changes be?

S: Since the larval mosquito develops in moist soil, draining or landfilling would stop its development as would the high salinity that would result from flooding. Draining, flooding or landfilling the marshes would also be effective in controlling punkies and tabanid flies.

Since the black fly develops in fast running water and the stable fly develops mostly in manure or seaweed, these methods would have no effect.

17. T: What are the disadvantages of environmental changes?

S: Marshlands are an integral part of the marine ecosystem. If they were destroyed, the nursery grounds for many non-pest organisms and the marsh's nutrient productivity would also be destroyed. (See Learning Experiences VI.A.3.a. (Mar. 4.) Marshes: Nature's Bounty; I.B.4.b. (Mar. 3.23) Distribution of Salt Marsh Life; V.B. (Mar. 4.2) Teacher Resource Guide to the Film "Crisis in the Estuary"; VI.B.1.a.2. (Mar. 4.31) Teacher Resource Guide to the Film "The Endangered Shore". These units are available from Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.)

18. T: How would you or your family use personal controls such as screens and repellents?

S: During the spring and summer, screens are put up in the windows and doors of homes to prevent the entry of insects and at the same time allow fresh air ventilation. Campers use mosquito nets and cheesecloth as preventives against flies while sleeping. Repellents such as "6-12" and "Off" are used directly on the skin or clothes as deterrents against biting flies.

19. T: What are the limitations of these methods?

S: Although screens are excellent for reducing the annoyance of biting flies in an enclosed space, they do not eliminate biting fly populations. Repellents are also very effective for personal protection, but only for a limited period of time.

20. T: All organisms are reduced in numbers as a result of disease and predation. How might this factor be used in the control of biting flies?

S: Introduce organisms which are the natural predators or disease-causing agents of biting flies. If these organisms are already present, their numbers might be increased.

D: Certain fishes are voracious feeders of mosquito larvae. As they are natural residents of salt marshes, their populations might be augmented by adding more fish. These fish may also be introduced to areas where they do not occur naturally (Rolston and McCoy, 1966, pp. 107-108).

The same may be done with bacteria and viruses which cause diseases in insects (Rolston and McCoy, 1966, p. 108). However, in both cases, organisms should not be added to the point of upsetting the natural balance of the ecosystem. For instance, certain viruses and bacteria may also be lethal to organisms other than biting flies and the fishes might consume organisms which are essential and beneficial to the marsh.

21. T: If one sex of the biting flies were raised in the laboratory in great numbers, sterilized, and then released in the marsh, what would happen?

S: The flies would be incapable of mating and producing any offspring, thereby decreasing the fly population.

D: Such a method was successfully used in controlling the screw-worm fly on a Caribbean island. Males were raised in the laboratory and sterilized by radiation. When released in large numbers, the female had less chance of successfully mating with a male and the population declined. The drawback of this method is that the sterile organism must be raised in the laboratory. However, chemical sterilants are being developed which can be applied to an area in a manner similar to insecticides (Harold and Oldroyd, 1964, p. 281).

22. T: One trapping method commonly used is a light trap. How many students are familiar with this type of trap?

S: Most students should be familiar with this trap since it is widely used. Also, they should be aware that flies are attracted to light.

23. T: How do these traps work?

S: Many flies are attracted to light at night. By attaching a catching mechanism such as a sucking fan, cyanide, or an electrified wire to the light, the flies are killed.

24. T: The salt marsh greenheads are perhaps the most bothersome summertime flies, affecting both humans and livestock. A specific type of trap has been developed for these pests. These traps have been very effective in decreasing the numbers of greenhead flies. In tests, over one million flies were captured during a three-year study. In the following questions, we will use the same evidence on the life habits of the greenhead that scientists used to develop this trap (Catts and Hansens, 1975, pp. 20-23).

These flies attack by flying upward toward their victim. How should the opening to our trap be oriented?

S: The opening should be facing toward the ground.

D: The size of the opening was tested by trial and error and found to be of optimum effectiveness at a size of 32 x 32 inches. The height of the box was found to be optimal at 16 inches.

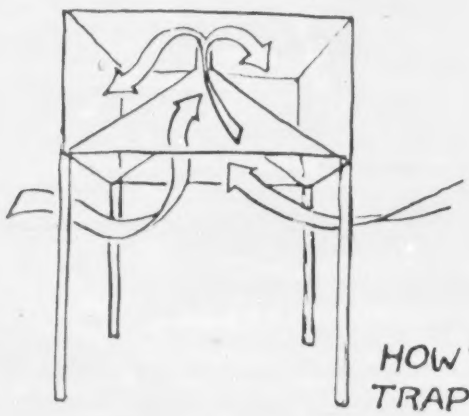
25. T: Knowing that these flies fly at an altitude of two feet, how far from the ground should the trap opening be?

S: 2 feet.

D: A design of the box trap is illustrated in Fig. 6, p. 21. Scientists have found that an upside down V-screen with a space of ½ inch at the top and a fold of 2 inches at the top is most effective. Furthermore, the top edge of the fold should be 4 inches from the screen which is covering the top of the box.

26. T: How does the fly get caught?

S: The fly flies up into the opening. Due to the V-shape of the bottom screen, the fly is guided through the entry slot into the screened-in area. Because of the slot extensions, the fly has a hard time escaping and eventually starves.



HOW THE TRAP WORKS

27. T: How is the fly attracted to the box trap? Scientists have found that greenheads are attracted to dark, warm, shiny surfaces. What should we do to our box to enhance its attractiveness to the flies?

S: Paint it a glossy black. Since dark colors absorb light, it will be warmer than the surroundings. The gloss makes it shiny.

28. T: Now that we have our trap, where should we put it? Studies show that the greenheads fly from the marsh upland. Their paths are usually along openings of low vegetation between stands of trees or tall brush.

S: The box traps should be placed on the upland side of the marsh edge along the flight paths of the flies.

ACTIVITIES

1. As a class project, construct one of these traps and test its effectiveness. Since biting flies are abundant during June through August, this optional exercise would have to be done either at the beginning or end of the school year. If done at the beginning, you may wish to construct the trap during the preceding spring. Remind the students that the trap is not as effective during these periods. Try to follow the directions given below as closely as possible. (From Catts and Hansens, 1975, p. 22). (See Fig. 6, p. 21) for completed moded).

Directions For Building The Box Trap

" 1. The optimal size for each side panel is about 16 x 32 inches. In our tests, larger and smaller box traps were less efficient. Furthermore, these dimensions allow five sides to be cut from a standard 4 x 8 foot panel with minimal waste. This means that the sides for five traps can be cut from 4 x 8 sheets of material.

2. The box is fastened to corner support legs so that its lower edge is 24 inches above the ground surface. This is important because the greenhead fly usually flies at about this altitude.

3. The bottom of the box consists of a gabled screen with a one-half inch trap entry slot at its ridge. The screen is folded at the entry slot so as to extend the slot two inches upwards and thus lessen the chance of escape by captured flies. The top edge of these slot extensions should be four inches below the flat screen top, or roof, of the box. Field tests showed that slot extensions doubled a trap's capture success.

4. The trap should be painted a glossy black to contrast with its surroundings and to absorb heat from the sun. Greenhead flies are attracted to glistening, or shining, warm targets.

5. The top and gabled bottom of the trap should be made of metal insect-proof screening. Plastic screening or sheeting will be damaged readily by birds seeking to get at the trapped flies.

6. The box sides must fit tightly against the screen top and gabled bottom so that the only access for fly entry or exit is the entry slot.

7. The cost of materials for a box trap is reasonable. Even without the use of salvaged or less durable materials, a trap can be built for less than ten dollars."

Every few days, count the number of flies caught in your trap. Keep a record of weekly catches and compare them. Do the numbers increase (in spring) or decrease (in fall) with time? Does the trap seem to be a good method for controlling biting flies?

2. Observe the morphology of any dead intact greenhead flies collected from the trap. They are characterized by their green head. Note the structure of the head and feeding apparatus (see Fig. 3, p. 18), recalling their mode of feeding. The Time-Life book, The Insects, has an excellent illustration of an insect's anatomy on pp. 44-45 and a photograph of a horse fly's head region on p. 46. (The greenhead fly is a type of horse fly).

3. Arrange to have an agricultural extension agent from your state talk about the biting fly problem and control methods used to combat these pests.

4. Field trips may be taken to state parks or preserves. Usually a member of the staff is familiar with insects and can lead a collecting trip. In Delaware, the Delaware Nature Education Center located at Brandywine State Park provides such service in September.

5. The class may wish to start an insect collection. Chapters 32 and 33 in the textbook by Borror and DeLong give detailed accounts of collecting and preserving insects and provide activities and projects in insect study. This book also aids in identifying insects.

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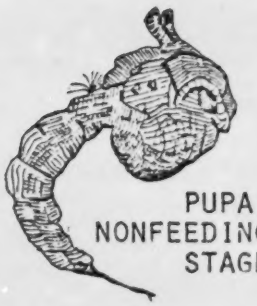
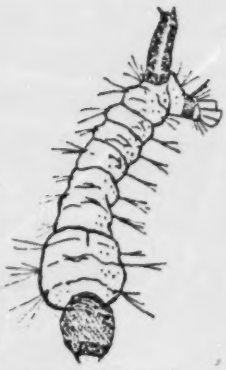
STABLE FLY
(STOMOXYS CALCITRANS)

MAGGOT

FAMILY: CULICIDAE

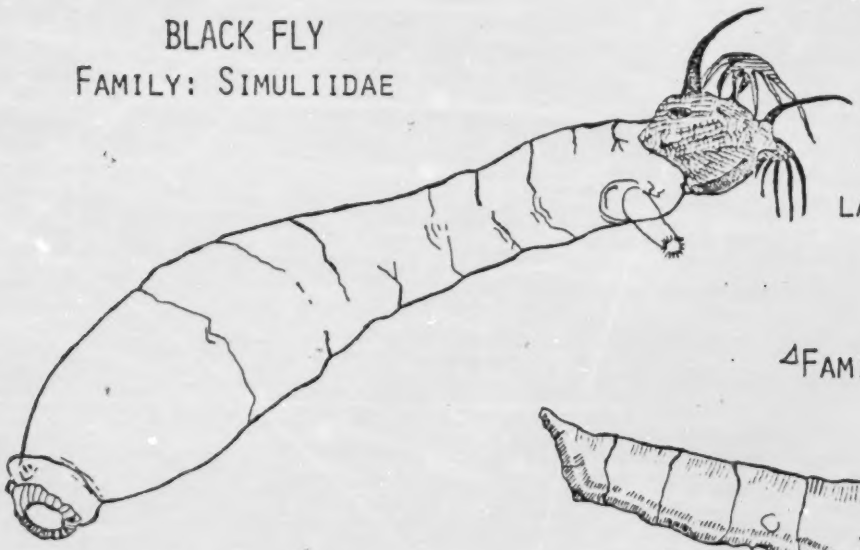


PUPA: NONFEEDING STAGE



LARVA: FEEDING STAGE

BLACK FLY
FAMILY: SIMULIIDAE

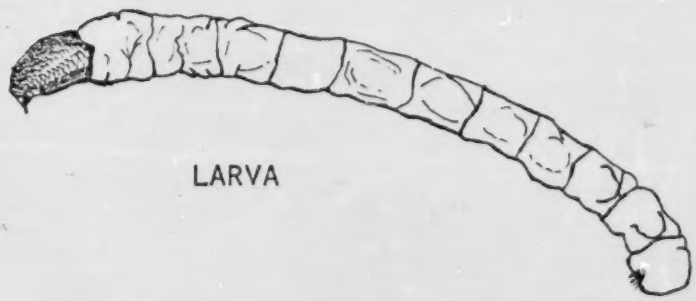


LARVA

FAMILY: TABANIDAE

TABANID LARVA

CULICOIDES SP.
PUNKIE



LARVA

FIGURE 2

▲FAMILY: CULICIDAE

SALT MARSH MOSQUITO

AEDES
SOLLICITANS

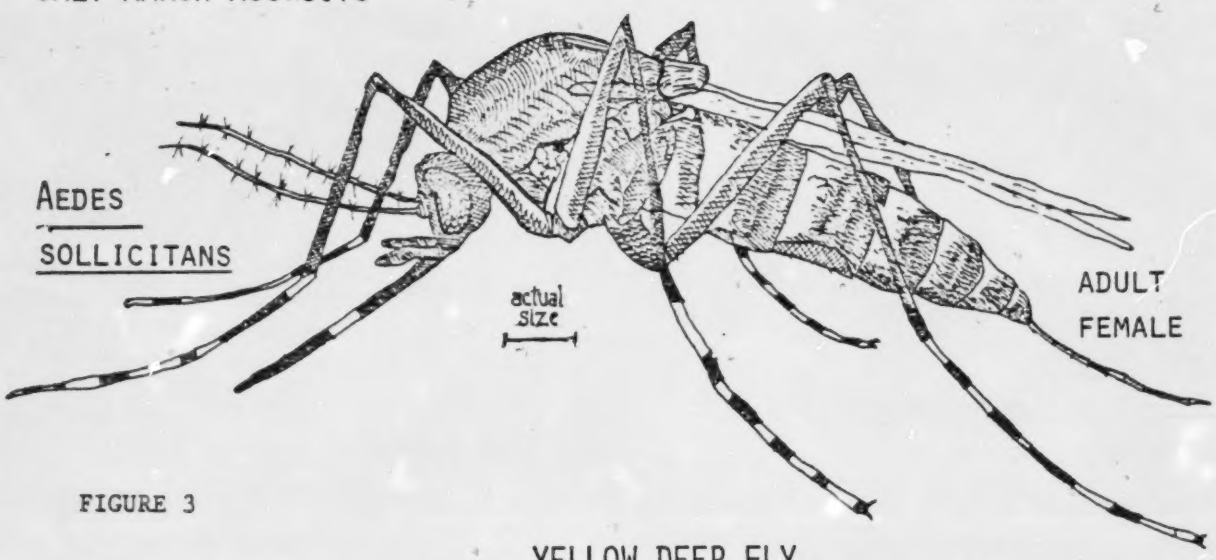
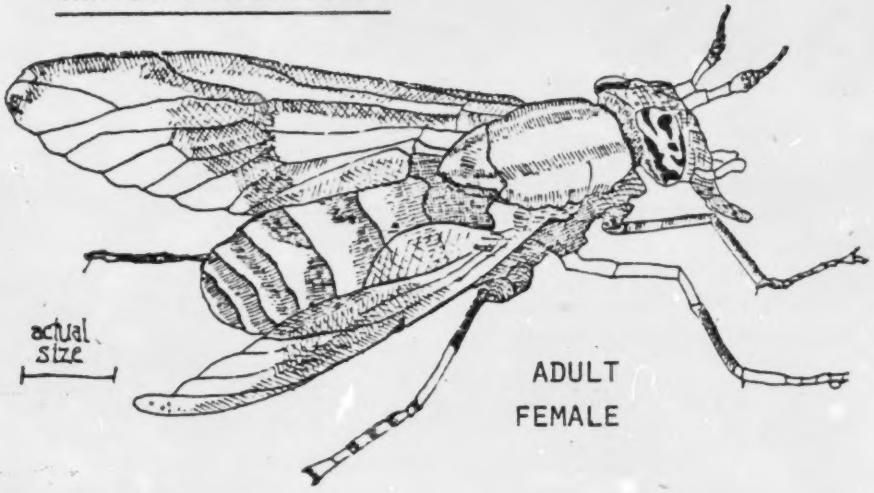


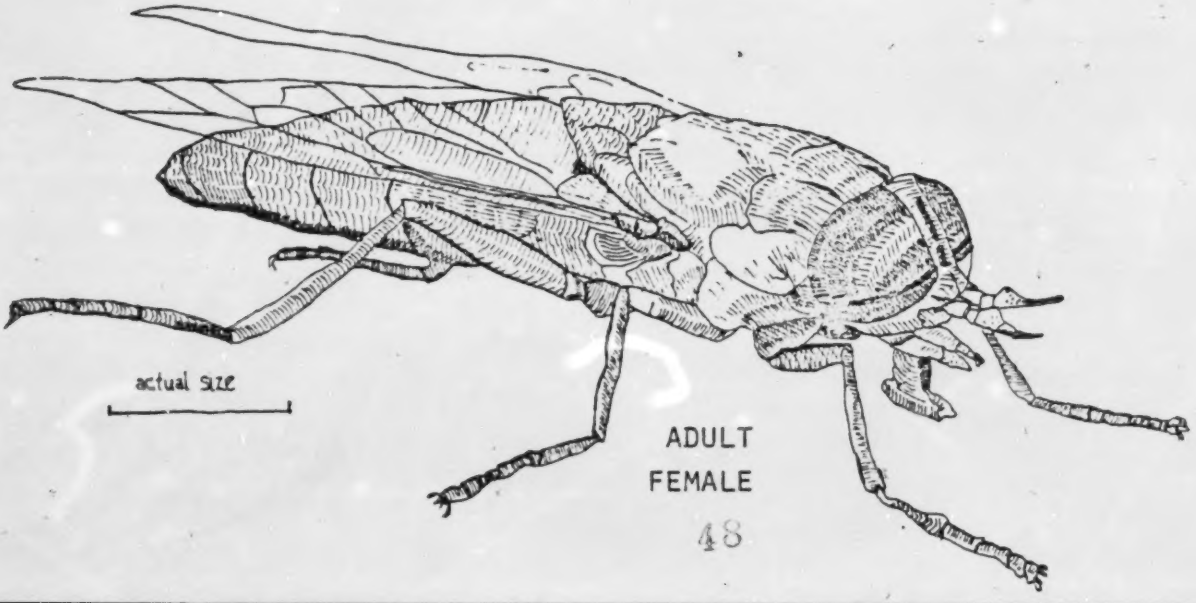
FIGURE 3

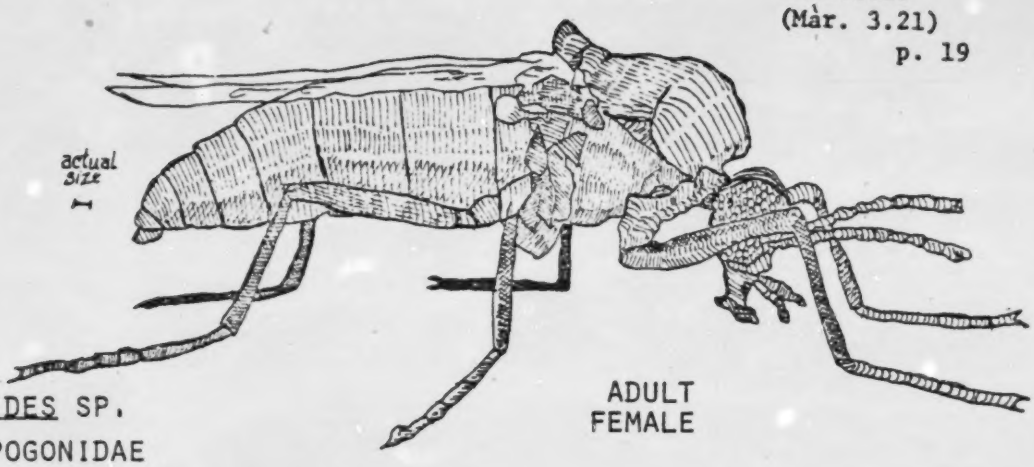
▲FAMILY: TABANIDAE

YELLOW DEER FLY
CHRYSOPS ATLANTICUS



SALT MARSH GREENHEAD
TABANUS NIGROVITATTUS

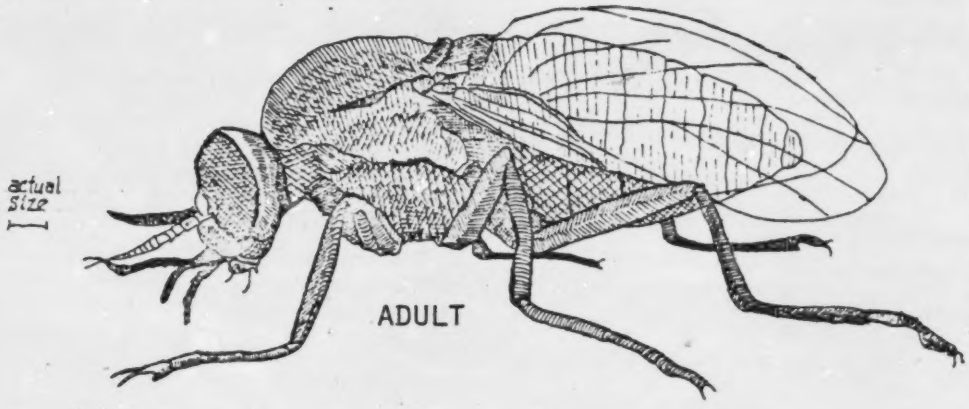




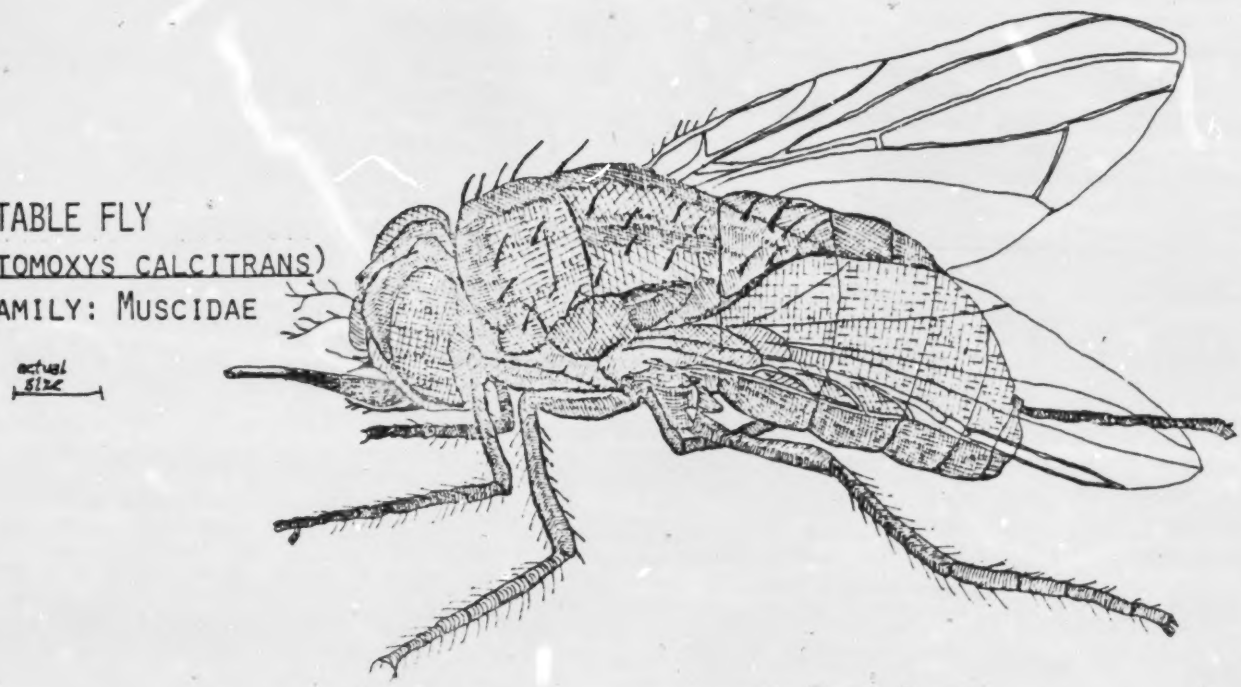
PUNKIE CULICOIDES SP.
△FAMILY: CERATOPOGONIDAE

FIGURE 4

BLACK FLY
(SIMULIUM SPP.)
△FAMILY: SIMULIIDAE



STABLE FLY
△(STOMOXYS CALCITRANS)
FAMILY: MUSCIDAE

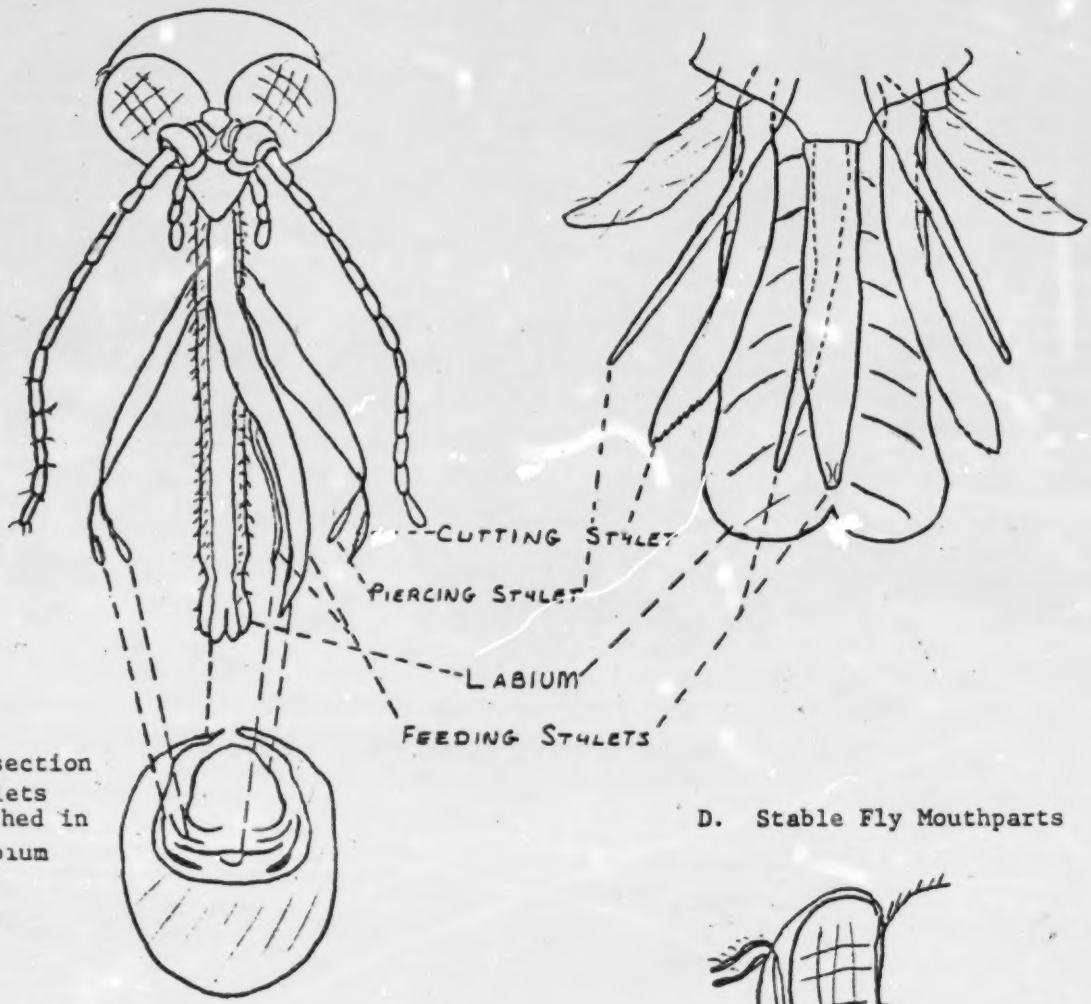


BY PAUL CATTS

Cep

FIGURE 5 BITING FLY MOUTHPARTS

A. Female Mosquito Mouthparts

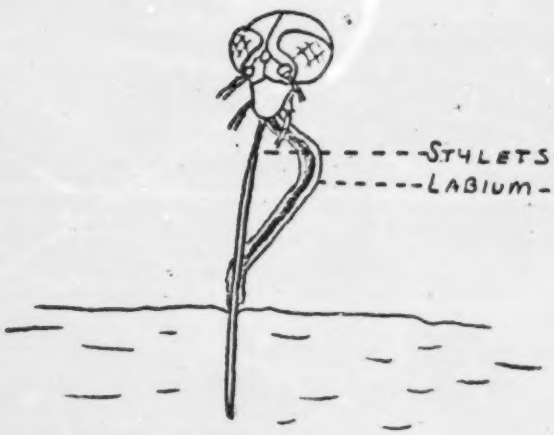


Cross section of stylets ensheathed in the labium

C. House Fly Mouthparts

D. Stable Fly Mouthparts

B. Mosquito Feeding



DIATOMS: NATURE'S AQUATIC GEMS

A Learning Experience for
Coastal and Oceanic
Awareness Studies

Produced by

MARINE ENVIRONMENT CURRICULUM STUDY
MARINE ADVISORY SERVICE
UNIVERSITY OF DELAWARE

and

POPULATION-ENVIRONMENT CURRICULUM STUDY
COLLEGE OF EDUCATION
UNIVERSITY OF DELAWARE

as part of a

PLAN FOR ENVIRONMENTAL EDUCATION

Fall 1974

Please send evaluations

of learning experiences

to

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COAST Project

310 Willard Hall Education Building

University of Delaware

Newark, Delaware 19711

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TITLE: DIATOMS--NATURE'S AQUATIC GEMS

* CONCEPT: I.B.4.

I. The earth is a finite natural system.

B. All living things have arisen from and are dependent upon the natural system of the earth.

4. THE INTERACTION OF ORGANISMS WITH THEIR ENVIRONMENT LEADS TO GREAT DIVERSITY AND WIDE DISTRIBUTION OF ORGANISMS

** MARINE CONCEPT: 3.21

3. Marine organisms interact in complex ecosystems.

3.2 Marine organisms are adapted to their environments in different ways.

3.21 MARINE ORGANISMS ARE ADAPTED DEVELOPMENTALLY, STRUCTURALLY, FUNCTIONALLY, AND BEHAVIORALLY TO THEIR WAYS OF LIFE.

GRADE LEVEL: 7-10

SUBJECT: Science

PERIODS: 2-4 (optional field trip)

AUTHOR: O'Neill, Hughes

Note to the Teacher:

The Augmented Marine Slide Collection produced by the Population-Environment Curriculum Study of the University of Delaware contains the following slides which you may wish to show your class and incorporate into this learning experience:

Slide 289: Centric Diatom, Guinardia flaccida, and Chrysophyte, Phaeocystis poucheti, in corner

Slide 290: Centric Diatom--Chaetoceros sp. (photomicrograph)

Slide 291: Centric Diatom--Leptocylindricus danicus (photomicrograph)

Slide 292: Pennate Diatom (photomicrograph)

Slide 293: Pennate Diatom (photomicrograph)

Slide 294: Pennate Diatom--Asterionella japonica (photomicrograph)

Slide 295: Pennate Diatoms--Epiphytic Diatoms (photomicrograph)

Slide 296: Pennate Diatom--Nitzchia sp. (photomicrograph)

* From A Conceptual Scheme for Population-Environment Studies, 1973. $2.50

** From Marine Environment Proposed Conceptual Scheme, 1973. No charge.

Both conceptual schemes are available from Robert W. Stegner, Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711

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- Key to Anagram

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- Collecting Benthic Diatoms
- Collecting Epiphytic Diatoms
- Collecting Edaphic Diatoms
- Collecting Diatoms Attached to Rocks, Glass, and Other Submerged Substrates
- Summary Exercise
- Key to Field Questions

III. The Main Features of Diatom Classification--A Reference for the Teacher

IV. Partial Bibliography

Student Directions:

Read the following discussion and answer the questions contained in it. Then use this information to complete the anagram found on pp. 14 and 15.

WHAT IS A DIATOM?

Diatoms are a type of microscopic algae which are yellowish or brownish in color. In size, they range from less than 10μ to about 1 mm. They are found in both fresh and salt water in any place where there is sufficient light to support photosynthesis. Diatoms may be planktonic (floating or drifting in the water), benthic (found on or near the bottom, but not attached to the substrate), epiphytic (attached to larger plants), or edaphic (living on the surface of muds). In addition, some types live on rocks, stones, or other materials in the water. Examine the drawings of various types of diatoms in Figure 1, Examples of Diatoms, pp. 4-5. Q-1: Would you say that diatoms are unicellular or multicellular? Most diatoms occur singly, but many species form characteristic chains or aggregates of individuals held together by protoplasmic junctions, mucilage, or interlocked spiny or hairy projections.

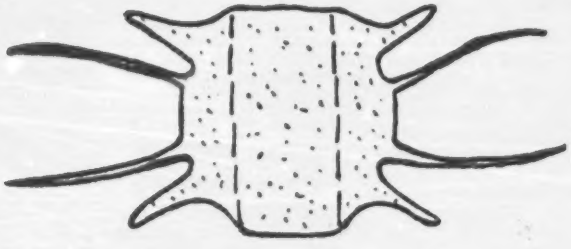
All diatoms are characterized by a secreted outer capsule called the frustule (frus'- ch$\bar{oo}$l), which is composed of two valves. The larger valve, or epitheca (ep - i - th$\bar{e}$'- ca), fits over the smaller valve, or hypotheca (h$\bar{y}$ - p$\bar{o}$ - th$\bar{e}$'- ca), much the same as the top and bottom of a petri dish fit together. A broad hoop-like band is attached to the edge of each valve. These bands overlap to form the girdle. Q-2: On Figure 2, Sketch of Pinnularia, Girdle View, p. 6, label the frustule, epitheca, hypotheca, and girdle.

To classify diatoms, scientists study the shape and markings of the frustules. In order to observe frustules more easily, all of the organic matter in the diatoms is dissolved away with acids. This acid treatment leaves the frustules undamaged. Q-3: What can you conclude about the chemical nature of frustules? Frustules are made of silica; this substance gives diatoms their glass-like appearance. Figure 3, Frustules of Several Diatoms After Acid Treatment, p. 7, shows the frustules of five different diatoms after acid treatment. The markings present (ridges, pores, and bumps) are species specific; that is, each species of diatom has its own peculiar set of markings. These characteristics, as well as the shape and size of the frustule, are used in identification.

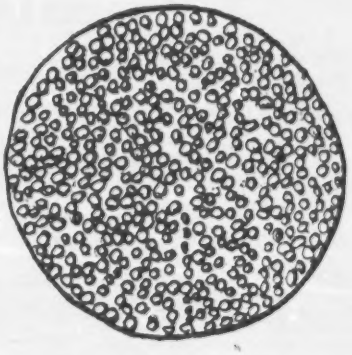
Scientists classify diatoms into two major groups. The centric diatoms are usually circular, disk-shaped, cylindrical, or triangular in the valve view. The valves of centric diatoms are radially symmetrical and sometimes have spines, horns, or other protrusions. This group consists of about 100 genera and 2,400 species; most of them are marine and planktonic. The pennate diatoms are generally elongated, oblong, feather-shaped, or boat-shaped. This group consists of about 70 genera and 2,900 species. About half of these are marine. In this group are found all of the soil diatoms, many of the freshwater species, and many of the marine benthic species. Q-4: Using this information, find three good examples of each type of diatom in Figure 1, Examples of Diatoms, pp. 4-5.

FIGURE 1: EXAMPLES OF DIATOMS

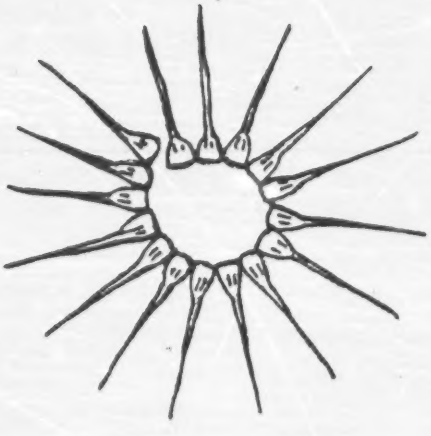
RHIZOSOLENIA SETIGERA



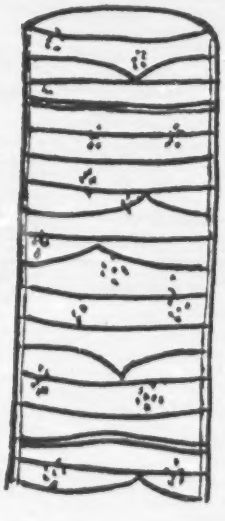
BIDDULPHIA MOBILENSIS



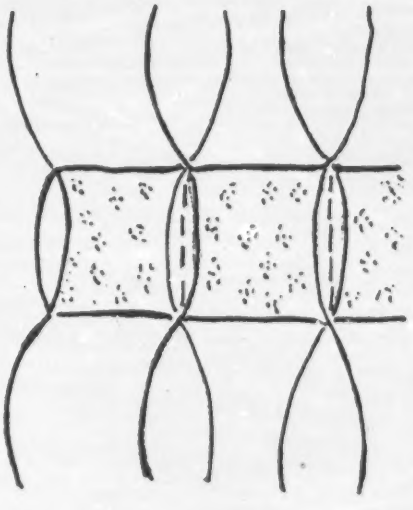
COSCINODISCUS SP.



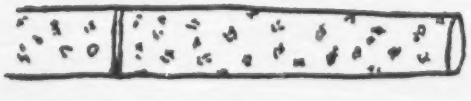
ASTERIONELLA JAPONICA



GUINARDIA FLACCIDA



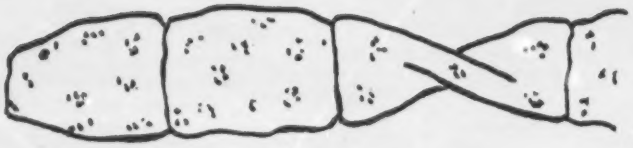
CHAETOCEROS SP.



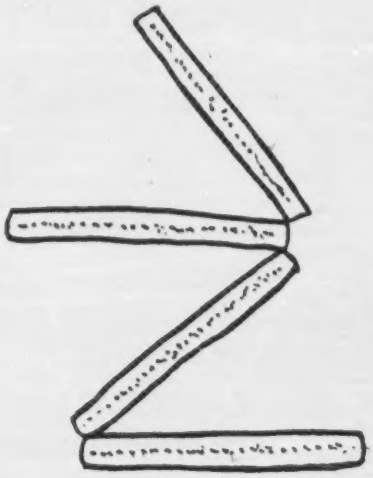
LEPTOCYLINDRICUS DANICUS

SKELETONEMA COSTATUM

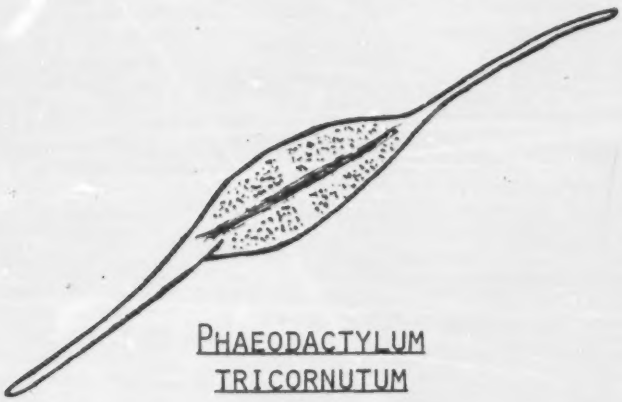
FIGURE 1: EXAMPLES OF DIATOMS (CONT.)



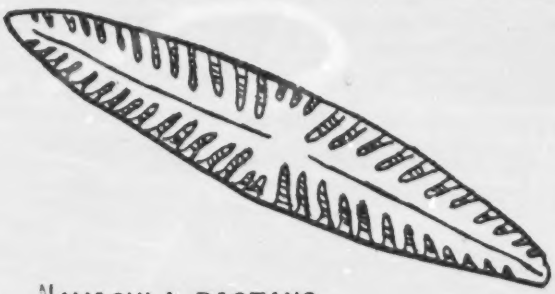
STREPTOTHECA THAMENSIS



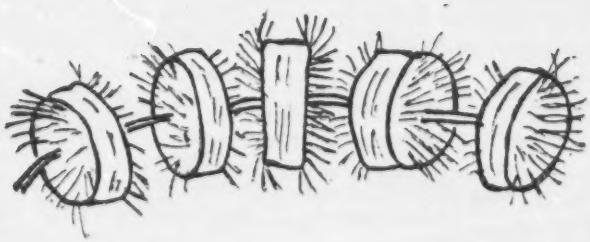
THALASSIONEMA NITZSCHIOIDES



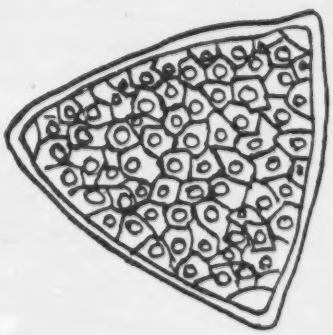
PHAEODACTYLUM TRICORNUTUM



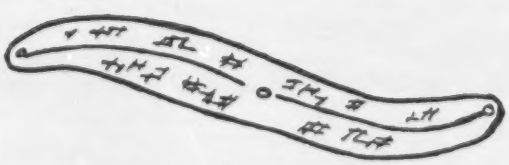
NAVICULA DISTANS



THALASSIOSIRA GRAVIDA



TRICERATIUM SP.



GYROSIGMA SP.

FIGURE 2: SKETCH OF PINNULARIA, GIRDLE VIEW

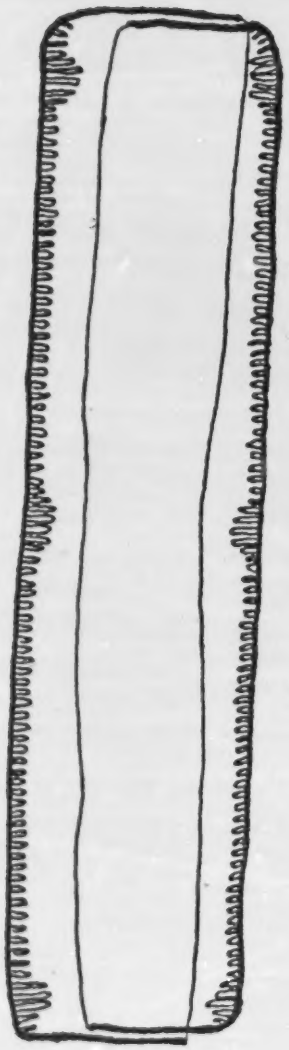
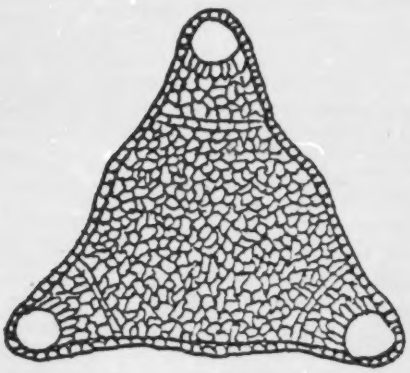
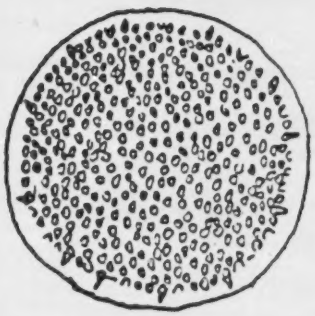


FIGURE 3: FRUSTULES OF SEVERAL DIATOMS AFTER ACID TREATMENT

DITYLUM SP.



HYDROSERA SP.



COSCINODISCUS SP.

NITZSCHIA SP.

MASTOGLOIA SP.

Many centric diatoms form filamentous chains; the chains resemble buttons or spools strung on a thread. (See the sketch of Thalassiosira gravida in Figure 1, p. 5) Many pennate diatoms occur singularly (e.g., Navicula distans in Figure 1, p. 5). Those that form aggregates do so with mucilage pods (e.g., Asterionella, Figure 1, p. 4, and Thalassionema, Figure 1, p. 5). Phaeodactylum (see Figure 1, p. 5) forms chains by interlocking its spindles.

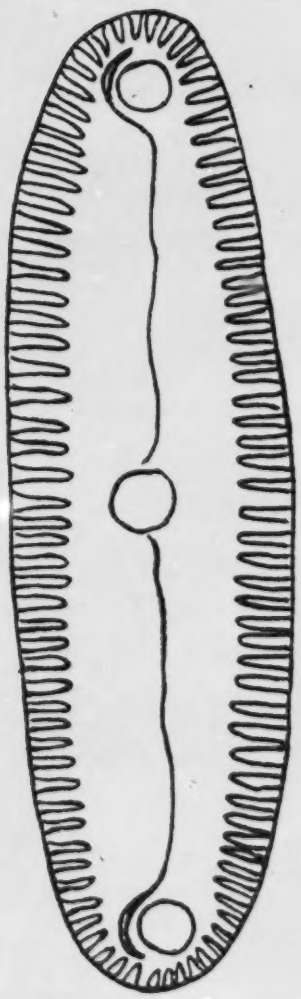
Many of the pennate diatoms, especially those living on muds, are motile. These motile diatoms possess thickenings in their frustules called nodules. Usually one nodule is found at each end of the cell, and one is found at the midpoint. They are called polar nodules and central nodules, respectively. These three nodules are connected by a long slit called the raphe (rāf) which is visible in the valve view. The raphe, wedge-shaped in cross section, is occupied by streaming cytoplasm in direct contact with the external environment. Q-5: Label the polar nodules, central nodule, and raphe in Figure 4, Sketch of Pinnularia, Valve View, p. 9. Q-6: The centric diatoms do not possess nodules or a raphe. Would you expect them to be motile? Q-7: Which structure, the nodules or the raphe, is probably responsible for diatom mobility? Q-8: How might this structure bring about diatom movement? Q-9: Considering this information, would you expect a diatom with a small raphe to be motile?

Inside the diatom the nucleus usually occupies a more-or-less central position. Cytoplasmic strands extend from the nucleus to other parts of the cell. Vacuoles are usually present. The chloroplasts, which carry out photosynthesis, may vary greatly in shape, number, and position from species to species. Some types of diatoms have only one chloroplast; others have many. They may be disklike, platelike, lobed, or irregular in shape. They contain a brown pigment which masks the chlorophyll that is also present and gives them their characteristic yellowish or brownish color. Q-10: What are the usual end products of photosynthesis? In diatoms, the carbon end product is an oil or fatty acid.

Diatoms normally reproduce by a simple mitotic process, as shown in Figure 5, Diatom Mitotic Reproduction, p. 10. First, the nucleus divides and the cytoplasm separates into two masses. Then, two new hypothecas are secreted inside each other and become independent. Daughter cells of some species may remain attached to each other to form chains or aggregates. This method of reproduction creates individuals of various sizes, as shown in Figure 6, Variation in the Size of Reproducing Diatoms, p. 11. One daughter cell will always have the size of the original cell, but the others will become smaller and smaller. This is because each of the newly secreted valves becomes a hypotheca and fits inside the existing valve, which becomes an epitheca in the daughter cell. Q-11: Is this method of reproduction sexual or asexual?

This process obviously cannot continue indefinitely. Maximum size is usually restored by the formation of auxospores. The small diatom discards its valves, increases greatly in size, secretes a light silica membrane and develops new valves of the maximum size for that species. Auxospore formation may be stimulated by attainment of absolute minimal size or by external conditions such

FIGURE 4: SKETCH OF PINNULARIA, VALVE VIEW



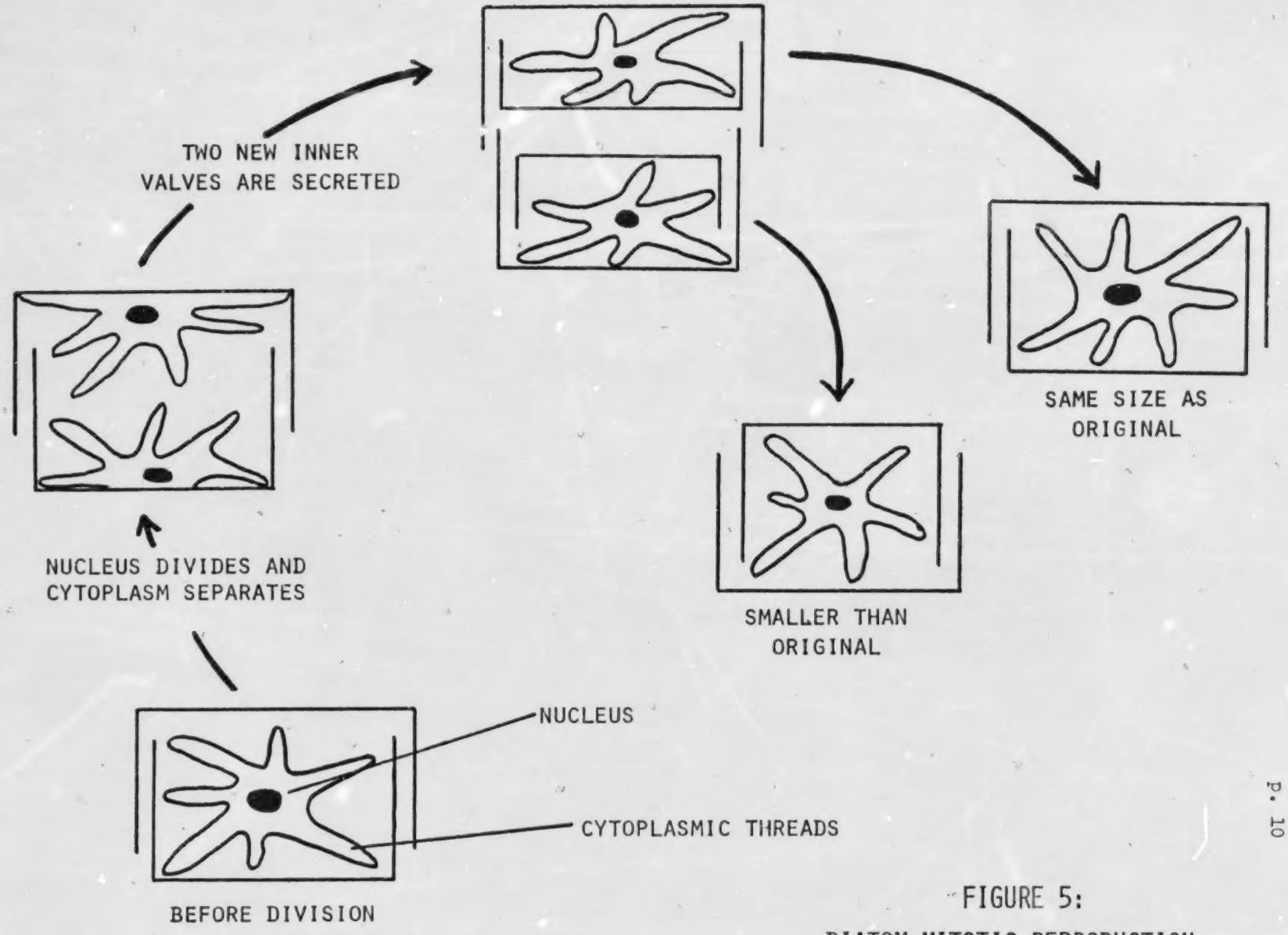


FIGURE 5:
DIATOM MITOTIC REPRODUCTION

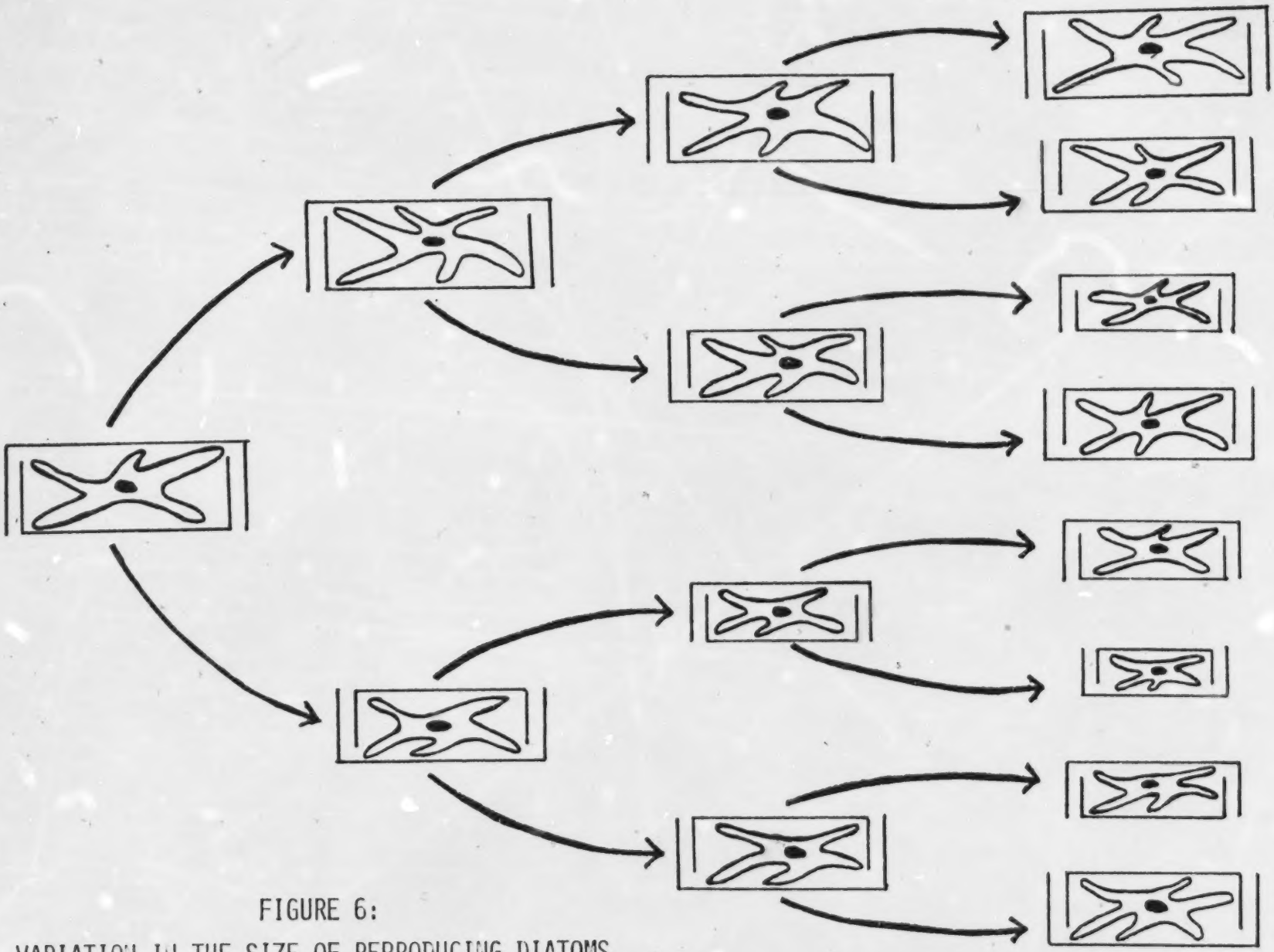


FIGURE 6:
VARIATION IN THE SIZE OF REPRODUCING DIATOMS

as light intensity and levels of dissolved nutrients or released metabolites. There is evidence that the normally diploid cells form haploid sexual gametes prior to auxospore formation, the auxospore being the diploid zygote. Q-12: If this is so, which type of cell division has occurred, mitosis or meiosis? Q-13: Is this type of reproduction sexual or asexual?

Under unfavorable conditions (such as low light intensities, low temperatures, or low levels of dissolved nutrients) some species form resting spores. During this process, the cell loses much of its cytoplasm and becomes round, forming a relatively dense mass which sinks into deeper water layers, or to the bottom in shallow areas. The valves are not cast off. When favorable conditions return, the spore germinates and begins reproducing.

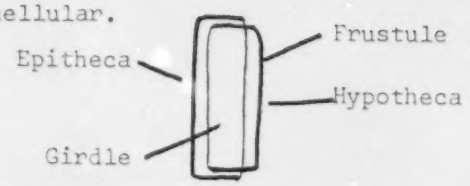
Because of seasonal changes or local reductions in nutrient levels, vast numbers of diatoms settle permanently below the euphotic (light-penetrating) zone and then die. This results in the accumulation of frustules on the sea floor. These deposits are called diatomaceous earth or diatomite. Uplifting of the sea floor has made this material available to man; it is added to many commercial products, including dynamite, detergents, polishes, paint removers, fertilizers, and toothpaste. Some swimming pools utilize diatomaceous earth filters. In addition, diatomaceous earth is frequently a component in insulation and sound-proofing materials.

Some of the earliest and best known fossil deposits of diatoms are found in the Moreno shales in central California. These deposits date back to the late Cretaceous Period (approximately 63-87 million years ago). Some diatom fossil records date back into the Triassic Period (181-230 million years ago).

Key to Questions:

Q-1: Unicellular.

Q-2:

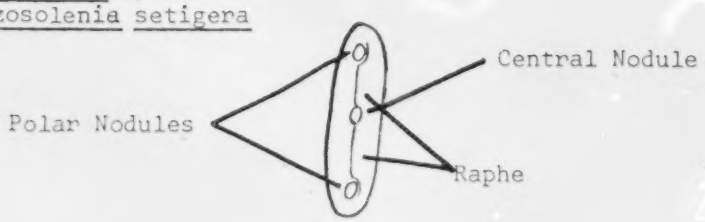


Q-3: Frustules are made of some type of acid-resistant material and are not made of organic matter.

Q-4:

Centric	Pennate
Biddulphia mobilensis	Asterionella japonica
Coscinodiscus sp.	Thalassionema nitzschioides
Guinardia flaccida	Navicula distans
Chaetoceros sp.	Phaeodactylum tricornutum
Leptocylindricus danicus	Gyrosigma sp.
Skeletonema costatum	
Streptotheca thamensis	
Thalassiosira gravida	
Triceratium sp.	
Rhizosolenia setigera	

Q-5:



Q-6: No.

Q-7: The raphe.

Q-8: There is probably friction between the streaming cytoplasm in the raphe and the external medium. The friction would allow movement.

Q-9: Yes, but probably less so than a diatom with a larger raphe.

Q-10: Carbohydrates and oxygen.

Q-11: Asexual.

Q-12: Meiosis.

Q-13: Sexual.

ANAGRAM

Use the clues below to complete the anagram on the following page.

Across

5--type of reproduction involving the formation of gametes and a zygote

6--a structure within the diatom cell which contains the hereditary material

7--the frustule is made of this compound

8--adjective meaning found on or near the bottom of a body of water

9--an end product of diatom photosynthesis

11--formed by the bands found at the edge of the epitheca and hypotheca

13--deposits of diatom frustules which form on the ocean floor (two words)

15--cell stage formed by some diatom species under unfavorable conditions (two words)

16--adjective meaning drifting

17--geologic period which occurred 181-230 million years ago

19--the slit-like structure found on the surface of some diatoms

20--product of the union of two gametes

21--cellular living material surrounding the nucleus

23--adjective meaning living on the surface of muds

Down

1--the body form by which diatoms restore themselves to maximal size, believed to be the result of sexual reproduction (plural)

2--the secreted outer capsule of a diatom cell

3--the smaller of the two valves which form the frustule

4--cellular structure which contains chlorophyll and carries out photosynthesis

6--a thickening in the frustule of motile diatoms

10--another name for diatomaceous earth

12--adjective meaning attached to larger plants

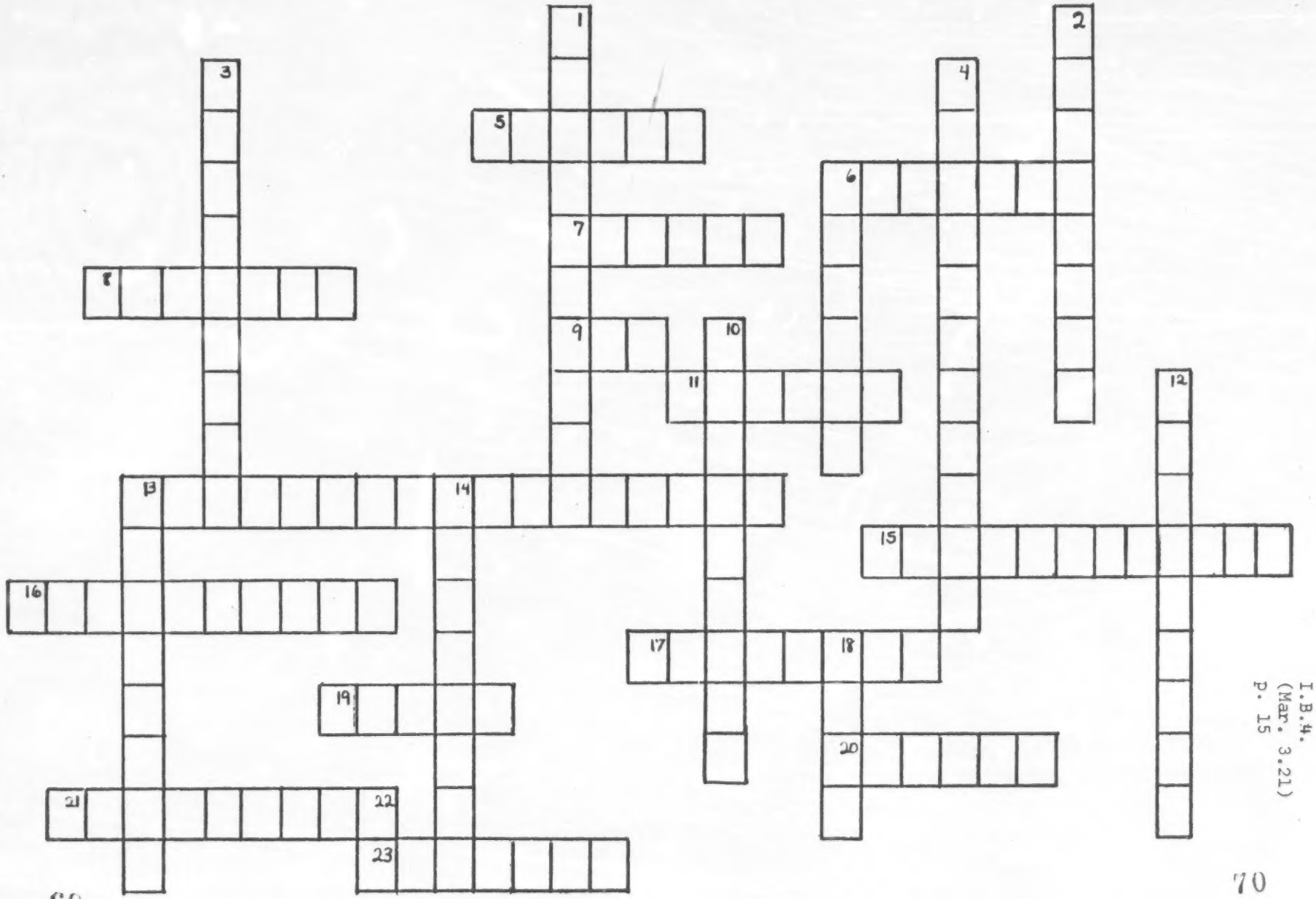
13--a type of explosive which contains diatomaceous earth

14--the larger of the two valves which form the frustule

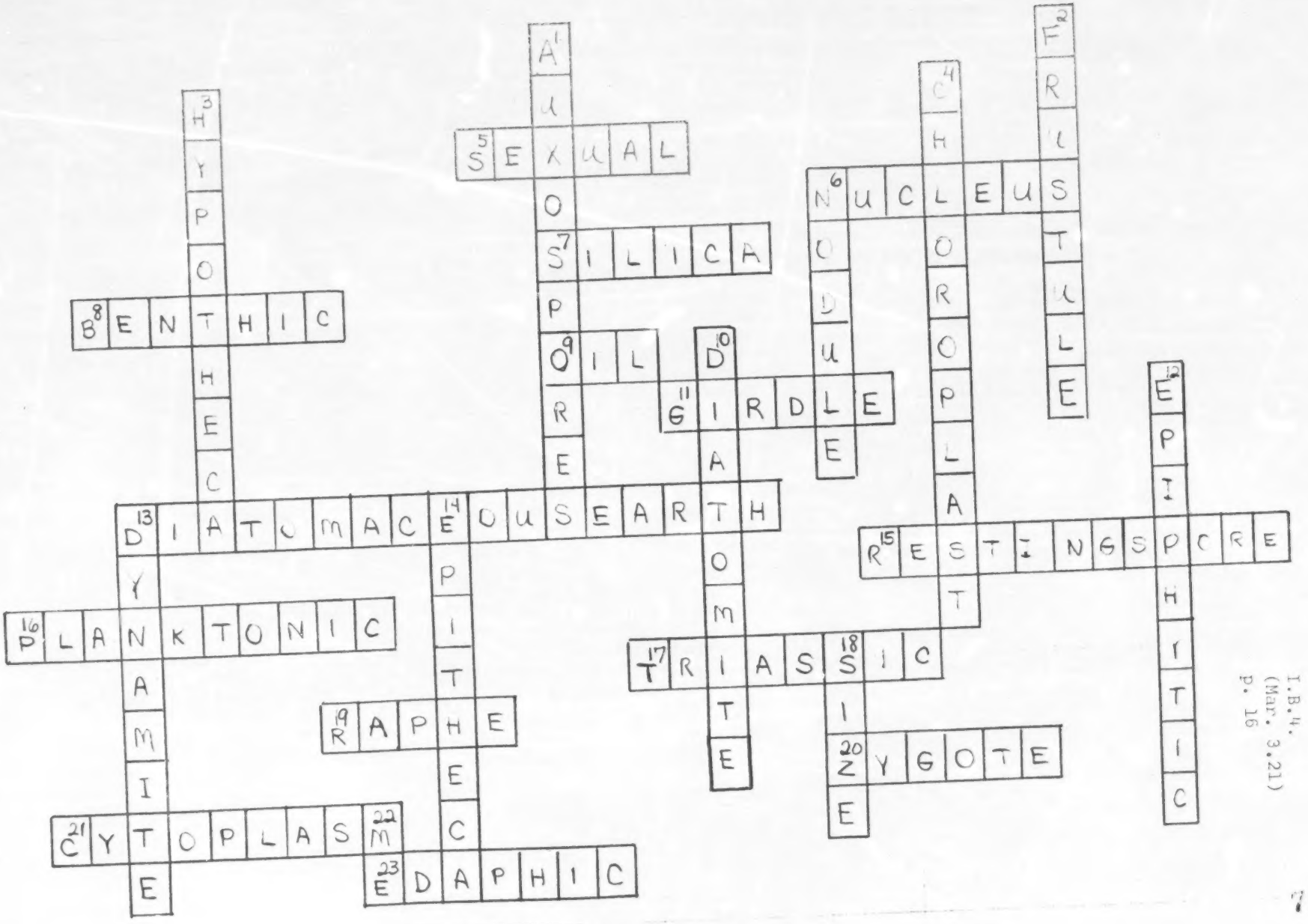
18--reduced each time diatoms divide asexually

22--first person objective case pronoun

ANAGRAM



KEY TO ANAGRAM



I.B.4.
(Mar. 3.21)
p. 16

Student Directions:

Below are instructions for collecting various types of diatoms. After making your collections and observing them you should be able to answer the questions in this section and write a summary paragraph.

HOW TO COLLECT DIATOMS

Since diatoms are found in many different places, there are several different methods commonly used to collect them.

Materials Needed in the Field:

Frozen orange juice cans with ends removed

Plastic wrap and tape or rubberbands to fit over the open ends of orange juice cans

Large containers for water (approximately 4 liters)

Small jars with lids to collect diatoms

Labels for collecting jars

Plankton net with #20 mesh (approximately 75μ)

Forceps, razor blade, or scalpel for scraping

Aspirator bottle

Materials Needed in the Lab:

Filter paper (soluble filters, if available)

Millipore filter (if available)

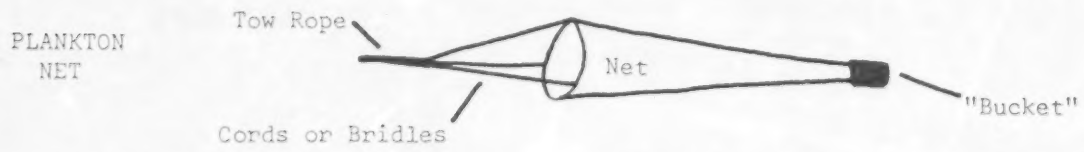
Medicine dropper or pipette

Glass slides and coverslips

Microscopes (with oil-immersion lens, if available)

Collecting Planktonic Diatoms

Obtain a plankton net with No. 20 mesh (see diagram) and tow the net



through the water. The diatoms will collect in the bucket at the end of the net. Place the plankton in a container for storage until you return to the lab. Label the container with your name, the date, and the collection site. Q-1: Some diatoms are fragile. Would this method of collecting be likely to damage them? Why or why not? Q-2: Is this method of collecting diatoms a

type of qualitative or quantitative sampling? Q-3: Does this method collect all of the planktonic organisms in the water that pass through the net?

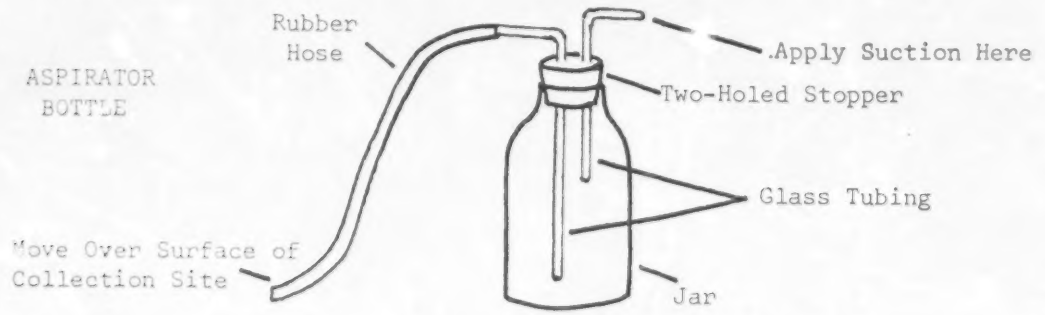
Upon returning to the laboratory, mix your sample, take a drop of the sample water, and place it on a glass slide. Cover the slide with a cover slip and observe the plankton with a microscope under low power, high power, and oil immersion (if available). Determine whether the specimens are centric or pennate. Identify them to genus if you can.

Another method of collecting planktonic diatoms is by collecting a whole water sample. Measure the volume of a large container (approximately 4 liters) and fill the container with a water sample. Cover the container to prevent evaporation and leakage. Label the container with your name, date, and collection site.

In the laboratory, filter the water (with soluble filter paper if available). The diatoms will be left on the filter paper. Observe them with a microscope. If soluble filter paper was used, dissolve the paper and collect the diatoms, then place them on a slide, cover with a cover slip, and view them. Determine whether they are pennate or centric. Identify any that you can. Q-4: Could this method be used to determine the number of diatoms present in a given volume of water? Q-5: Will other types of plankton also be present? Q-6: If so, how could you tell the diatoms from the other plankton?

Collecting Benthic Diatoms

Obtain an aspirator bottle. Place the tube a short distance above the surface of the bottom and suck up the surface layer (see diagram).



Store this material in a container until you return to the laboratory. Label the container with your name, date, and collection site.

In the lab, place a drop of the sample material on a glass slide, cover with a cover slip, and observe under a microscope. Determine whether the specimens are pennate or centric; identify any that you can.

Collecting Ephiphytic Diatoms

There are a number of ways you can collect epiphytic diatoms. Often the best way is to squeeze fairly large samples of the plants to which the diatoms are attached. Collect the liquid in a collecting jar and label the jar properly. Another way to collect diatoms attached to larger plants is to scrape the stems or undersides of leaves of those plants. Place the scrapings in the collecting jar and label properly. Sometimes small portions of the plant may be collected, but use this method only if you are having little success with the other two methods. After returning to the lab, prepare slides of the collected diatoms and observe them. Determine whether the diatoms are centric or pennate; identify any that you can.

Collecting Edaphic Diatoms

To collect these diatoms which live on mud surfaces, take a frozen orange juice can with both ends removed. Place one end of the can over the sample area and push it into the mud to obtain a core sample. Label your sample and identify the top surface of the mud. Seal both ends of the can with plastic wrap and tape or rubber bands to prevent water evaporation. Collect a water sample at the site also. Immediately upon returning to the laboratory, filter a portion of the collected water sample. Moisten a sheet of filter paper with some of this filtered water and place it on the top surface of the mud sample. Let it sit for 10-24 hours. By that time almost 90% of the live diatoms should have moved onto the filter paper. Observe the diatoms directly on the filter paper, or rinse them off with more filtered water, make a slide, and observe. Q-7: The diatoms went from the mud to the filter paper. How do you think they were able to do this? Q-8: Does this method of collecting diatoms limit the types found? Why or why not? Look for motile diatoms in your collected and processed samples. Examine them closely. Q-9: Do they have any cilia or flagella which would account for their movement? Compare diatoms that appear to move with some of those that do not. Q-10: Do those that move have any special shapes or structures which would permit them to move? If so, describe the shape or structure.

Collecting Diatoms Attached to Rocks, Glass, and Other Submerged Substrates

Scrape the surface of the substrate and collect the material in a small container. Add a small amount of water from the sample area to the container, and label it properly. In the laboratory, prepare and observe a slide from these materials. Determine whether the specimens are centric or pennate; identify any that you can.

Summary Exercise:

After you have observed diatoms collected from several different types of areas, write a paragraph summarizing your observations. Did the diatoms taken from the different places have different characteristics? Relate the structures and characteristics of those diatoms to their modes of life.

Key to Field Questions

Q-1: Yes, possibly. The water in the jar is relatively calm; however some damage may occur while the diatoms are being collected by the plankton net.

Q-2: Qualitative, since the volume of water passing through the net is not measured.

Q-3: No, it collects only those which cannot fit through the mesh of the net.

Q-4: Yes. Accuracy depends upon number of samples and accuracy of your technique.

Q-5: Probably.

Q-6: Diatoms are unicellular and have silicon frustules which are visible. Also, diatoms are rather small.

Q-7: The diatoms were probably motile.

Q-8: Yes--only those that are able to move would be present. This eliminates many types of diatoms.

Q-9: No, diatoms do not have cilia or flagella.

Q-10: Close inspection of motile diatoms should show that they are pennate and possess a raphe running the length of the cell, from one polar nodule to the other.

THE MAIN FEATURES OF DIATOM CLASSIFICATION--
A Reference for the Teacher

"Order Centrales or Centricae:

Diatom, usually circular, disc-shaped, cylindrical, or triangular. Valves radially symmetrical with radially disposed striae or concentric markings; sometimes with spines, horns, or other protrusions; no raphe; cells non-motile; cytoplasm with numerous small chromatophores; resting spores and auxospores commonly formed; gametes, where known, anisogamous with motile flagellated male gametes. Mostly marine, planktonic. About 100 genera and 2400 species....

"Suborder Biddulphiodeae:

Box-shaped; prevalvular axis not much longer than, or shorter than, valvular axis; valves usually oval, sometimes polygonal, circular, or semicircular; unipolar, bipolar, or multipolar--each pole with an angle, horn, or spine, or with both angles and horns. Some representative forms follow:

Family Biddulphiaceae: Bacteriastrum, Bellerochia, Biddulphia, Cerataulina, Ditylum, Hemiaulus, Lithodesmium, Terpsinoe
Family Chaetoceraceae: Chaetoceros
Family Eucampiaceae: Climacodium, Eucampia, Streptotheca

"Suborder Discoideae:

Disc-shaped or cylindrical, valve circular, flat, or convex, or sometimes hemispherical; zonal diameter shorter than valvular diameter; sculpture radial or concentric, related to a central pole; spines or horns frequent.

Family Coscinodiscaceae: Arachnodiscus, Asteromphales, Coscinodiscus, Cyclotella, Planktoniella
Family Melosiraceae: Melosira, Peralia
Family Skeletonemaceae: Skeletonema, Stephanopyxis
Family Thalassiosiraceae: Coscinosira, Lauderia, Schröderella, Thalassiosira

"Suborder Solonoideae or Soloniineae:

Valves oval or circular; cells long, cylindrical, with numerous intercalary bands; no internal septa; united in chains by their valves.

Family Corethronaceae: Corethron
Family Soleniaceae: Atthenya, Rhizosolenia, Dactyliosolen, Guinardia, Leptocylindrus

"Order Pennales or Pennatae:

Elongated, oblong, or feather- or boat-shaped, the valves with two planes of symmetry, usually elongated, with the striae more or less transverse to the apical axis; no spines; a longitudinal groove, the raphe, present in the majority; those possessing a true raphe are motile, with a gliding movement; chromatophores commonly large, platelike, lobed, or somewhat rolled up into a partial cylinder, usually only one or two present; no resting spores formed; gamete where known, isogamous, not flagellated.

"About 70 genera and 2900 species, somewhat more than half marine. This group includes all the soil diatoms, the majority of freshwater species, and a great many marine diatoms, especially the benthic species....

"Suborder Araphidineae:

No raphe or pseudoraphe; nonmotile.

Family Fragilariaceae: Asterionella, Fragilaria, Thalassiothrix
Family Tabellariaceae: Striatella

"Suborder Biraphidineae:

Well-developed raphes on each valve; commonly motile, with gliding motion .

Family Cymbellacceae: Amphora, Cymbella
Family Naviculaceae: Amphiphora, Navicula
Family Nitzschiaceae: Bacillaria, Hantzschia, Nitzschia, Phaeodactylum

"Suborder Monoraphidineae:

One raphe only; other valve has only a pseudoraphe or a rudimentary raphe.

Family Achnanthiaceae: Achnanthes, Cocconeis

"Suborder Raphidiodinae:

Raphe apparent only at the terminal nodules, not extending the length of the valve.

Family Eunotiaceae: Eunotia, Peronia"

(McConnaughey, 1970)

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*Indicates suitable for high school students.